REPORT RESUMES

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ELECTROMECHANICAL TECHNOLOGY. A FIELD STUDY OF ELECTROMECHANICAL TECHNICIAN OCCUPATIONS, PART I. A POST-HIGH SCHOOL TECHNICAL CURRICULUM, PART II. (TITLE SUPPLIED)

BY- RONEY, MAURICE W.
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A FIELD STUDY OF THE ELECTOMECHANICAL TECHNICIAN OCCUPATION WAS CONDUCTED IN TWO STAGES. IN THE FIRST PHASE, PERSONAL INTERVIEWS WERE CONDUCTED IN 26 INDUSTRIAL ORGANIZATIONS SELECTED BY SIZE, PRINCIPAL ACTIVITY, AND GEOPGRAPHICAL DISTRIBUTION. IN THE SECOND PHASE, A BRIEF QUESTIONNAIRE WAS USED TO OBTAIN A BROAD SAMPLE OF THE QUANTITATIVE NEED FOR ELECTROMECHANICAL TECHNICIANS. IN GENERAL, THE STUDY SUCCEEDED IN ITS MAJOR OBJECTIVES OF IDENTIFYING OCCUPATIONAL AND EDUCATIONAL NEEDS IN THE NEW AND EMERGING OCCUPATION OF ELECTROMECHANICAL TECHNOLOGY. THE RESULTS OF THE STUDY INDICATED A CLEAR AND PRESSING NEED FOR EXPERIMENTATION AND INNOVATION IN THE DEVELOPMENT OF TECHNICAL EDUCATION FOR NEW AND EMERGING OCCUPATIONS. THE EVIDENCE POINTED TO A SPECIFIC NEED FOR NEW TRAINING PROGRAMS IN ELECTROMECHANICAL TECHNOLOGY. THE INFORMATION OBTAINED WAS USED TO PREPARE A BASIC CURRICULUM PLAN FOR A 2-YEAR, POST-HIGH SCHOOL PROGRAM IN ELECTROMECHANICAL TECHNOLOGY. THE CURRICULUM IS PRESENT IN PART II OF THIS REPORT. (TC)

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FINAL REPORT
Project No. 46-27
Contract No. OE-6-85-057

ELECTRO-MECHANICAL TECHNOLOGY

A Field Study of
Electro-mechanical
Technician Occupations

Part I

September 1966

U.S. DEPARTMENT OF
HEALTH, EDUCATION AND WELFARE

Office of Education
Bureau of Research

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ELECTRO-MECHANICAL TECHNOLOGY

A Field Study of Electro-mechanical Technician Occupations

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Maurice W. Roney

September 1966

The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

The Oklahoma State University
School of Industrial Education

Stillwater, Oklahoma

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INTRODUCTION

The Problem

There is increasing evidence that, as engineering organizations increase in size and complexity, engineering work tends to diversify. New and emerging technical occupations often require combinations of skills that have previously been considered highly specialized. Technical skills that cross mechanical, electrical, electronic, or chemical fields are necessary in some of the newer industrial activities: in the missile industry, in automated production facilities, and in certain field services of an engineering or scientific nature.

Preparatory training for new and emerging technical occupations requires new combinations of technical subject matter. In recent years, technical education has developed a pattern of two-year, post-high school programs that relate to certain fields of engineering education such as electrical engineering, mechanical engineering and chemical engineering. It seems reasonable to assume that some phases of technical education should be revised to include training that cuts across two or more of the traditional fields of engineering.

The problem with which this study was concerned was to determine if a substantial need exists for instructional services combining knowledge and skill in two related fields, each of which customarily has been treated as a separate field of study.

Two of the traditional engineering fields that appeared to be closely related were electrical engineering and mechanical engineering. Combinations of skills from these two fields were expected to appear in such applications as missile guidance systems, data processing equipment, automatic industrial production equipment, and in an almost endless variety of control or actuating devices. Technicians working in engineering activities where both electrical and mechanical principles are applied were expected to need and use technical concepts in both fields.

Objectives of the Field Study

The specific objectives of the field study were: 1) to obtain a measure of the need for technicians with skill and knowledge encompassing both mechanical and electrical principles and applications and 2) to identify skill and knowledge essential to electro-mechanical technician occupations, so that these requirements could form a basis for the development of a preparatory training program of approximately two years.

A tertiary objective was to develop a method of occupational analysis for new and emerging occupations which require skills that cut across traditional fields of educational specialization.

PROCEDURE FOR THE FIELD STUDY

Development of the Procedure

The relative newness of the electro-mechanical occupations precluded the use of conventional occupational analysis techniques in determining quantitative and qualitative manpower needs. The Standard Industrial Classifications do not specifically identify industrial activities that require personnel with this combination of skills. Furthermore, no standard terminology was available to describe either the job functions or educational requirements in these occupations. In view of this dearth of established guidelines, it was decided to employ an experienced occupational analyst to conduct a series of interviews with personnel in selected industries thought to employ technicians whose responsibilities and work functions involved both electronic and mechanical systems and/or devices. It was recognized that the decision to place a prime responsibility for the field study in the hands of one individual made the selection of this person all-important. Ideally, this person should have experience in electrical and mechanical work of an engineering or technical nature. He should also have experience as a teacher. The individual selected, Professor Austin E. Fribance, Research Consultant from the Rochester Institute of Technology, Rochester, New York, met all of these requirements. In addition, he had valuable experience as a consultant to the U.S. Office of Education in the development of curriculum guides for two-year technical education programs in mechanical technology and instrumentation technology.

A Panel of Consultants (see Appendix A) was selected to provide advisory services and to assist in planning and conducting the field study. These consultants were selected to represent several kinds of industrial activities such as manufacturing, research, distribution, and service. The organizations selected included: the computer industry, electronics companies, government agencies, instrument makers, technical schools, and technical publishers. The Panel played a vital role in the development and conduct of the study. In fact, the success of the study, as measured by the consistency and validity of the findings, was due primarily to the leadership and specific contributions of the Panel members.

The first phase of the field study was organized and planned by the research staff of the School of Industrial Education of the Oklahoma State University and the Panel of Consultants at a meeting in Oklahoma City, Oklahoma, on November 10 and 11, 1965. At this meeting, the Panel, using the definitions shown in Appendix B, identified the following general areas in which technicians might work both electrical and mechanical devices and systems:

1. Customer or product service.
2. Product design and testing. (Research and Development)
3. Building and testing the test equipment.
4. Building and testing of prototypes. (Research and Dev.)
5. Production equipment.
6. Quality assurance.
7. Test equipment maintenance.
8. Production equipment maintenance.
9. Environment assimilation.
10. Product engineering. (Design changes when machine is in production.)
11. Operation of research equipment.

The panel then selected a representative sample of 55 industrial organizations in six geographical areas as shown in Appendix C. Panel members also provided names of persons to contact in certain of these organizations and, subsequently, either wrote or called these persons to arrange interviews.

The remainder of the Oklahoma City meeting was devoted to planning the industrial interviews to be conducted by Professor Fribance.

During the first three months of 1966, Professor Fribance conducted a series of 53 separate discussions, covering a total of 26 industrial organizations and 60 individuals.

After assessing the results of these 53 interviews, it was apparent to the research staff that the consistent pattern of the findings made it doubtful that further interviews would produce additional new information. The Panel of Consultants was reconvened to study the results thus far obtained and to plan further investigation. The second meeting of the Panel was held at the Hotel Adolphus in Dallas, Texas on April 13. It was agreed at this time that further field interviews would not be appropriate. However, it was felt that another measure of need would be valuable in justifying the expense of establishing new programs of training in electro-mechanical technology.

Accordingly, a brief questionnaire was designed for mailing to selected industrial organizations to obtain the following:

1. Certain specific information on quantitative needs of technicians
2. General information on problems of providing supplementary training in industry.
3. Suggestions for the content and organization of an Electro-mechanical Technology curriculum.

Also at the Dallas meeting, the Panel reviewed a proposed curriculum outline for a two-year, post-high school pre-employment training program for electro-mechanical technicians. This curriculum was developed by the research staff using material obtained in the field study and was included in the material sent to industrial firms along with the questionnaire. Respondents were asked to evaluate the curriculum in the light of their needs for technical personnel. The curriculum outline, by providing a description of the level and scope of training, served to identify and describe the type of technical personnel under consideration.

Procedure for Interviews with Industrial Personnel

The initial interview phase of the field study was conducted by Professor Fribance. Professor Fribance's background in electrical and mechanical engineering, his experience as a teacher of both technical and engineering work, and his experience as an occupational analyst gave him unique and highly effective ways of establishing rapport with industrial representatives in the interview process.

The Panel of Consultants provided the names of key individuals in each company visited. The judicious selection of knowledgeable persons by panel members contributed much to the success of the field study. When the first person contacted thought that others could answer the questions more competently, these others were brought into the discussion or additional meetings were arranged. Each interview involved from one to six interested individuals. Frequently, several interviews were held in separate divisions of the same plant.

Persons interviewed were in the following categories.

1. Personnel department representatives.
2. Managers of departments employing technicians for:
    a. Manufacturing
    b. Quality Control
    c. Field Service
    d. Research and Development
    e. Production
3. Managers of educational and planning services.

The time required for a typical interview varied from one hour to one day. When four or five separate discussions were required, one day was barely adequate. Because of the impossibility of predicting the number of separate meetings or the amount of preparation (in one case, a participant came with three pages of notes), it became impracticable, in most cases, to schedule more than one visit per day. Moreover, the physical separation of the various companies often made it necessary to travel several hours, to reach the next company to be studied.

Without the names provided by the panel members and their active participation in arranging meetings, the interviews would have been far less productive. Directing letters to people who are known to be concerned with the problem is the most important step in arranging interviews. This approach might well be followed in similar studies to insure successful interviews and willing participants.

The data collected in this phase of the study consisted of comments (sometimes personal) and opinions. No attempt was made to obtain responses to identical questions from each person interviewed. A portable tape recorder was used to save time during interviews and to insure maximum accuracy.

The type and size of organizations included in the interview phase of the study are shown in Table I. An arbitrary size classification was used; large employers were those with 5,000 or more employees; medium size companies employed 500 to 4,999; and small organizations were those with less than 500.

The industrial organizations were classified as follows: manufacturing, research and development, design, and calibration and test. In most cases, the visits included interviews with personnel responsible for more than one of these activities. No attempt was made to correlate responses with activities, but in general, no apparent difference developed in the study.

TABLE I

TYPE AND SIZE OF 26 ORGANIZATIONS IN WHICH FIELD INTERVIEWS WERE CONDUCTED

INDUSTRY OR ACTIVITY VISITED	SIZE (L.M.S.)*	TYPE OF INDUSTRY OR ACTIVITY			
		MANUFACTURING	RESEARCH & DEVELOPMENT	DESIGN	CAL & TEST
1. Sylvania Electric Corp.	L	X	X	X	
2. Gillette Safety Razor Co.	M	X	X		
3. Electric Boat Division of General Dynamics	L	X			
4. Bodine Electric Corp.	S	X			
5. International Business Machines Corp.	L	X	X	X	X
6. Bethlehem Steel Co.	L	X			
7. Dupont de Nemours Co.	L	X	X		
8. Electronic International	S		X		X
9. Goddard Space Flight Ctr.	M		X	X	X
10. Eastman Kodak Company	L	X		X	
11. Xerox Corporation	M	X	X	X	
12. Texas Instruments Corp.	L	X	X		X

continued on next page.

TABLE I
(CONTINUED)

INDUSTRY OR ACTIVITY VISITED	SIZE (L.M.S.)*	TYPE OF INDUSTRY OR ACTIVITY			
		MANUFACTURING	RESEARCH & DEVELOPMENT	DESIGN	CAL & TEST
13. Ling-Temco-Vought	M	X		X	X
14. Gen Dynamics (Aircraft)	L	X			
15. General Electric Co.	M	X		X	X
16. Motorola Corporation	L	X	X		X
17. Kaiser Electronics Corp.	S	X			X
18. Consolidated Electro-dynamics	M	X	X	X	X
19. Beckman Instruments	M	X		X	X
20. Gen. Dynamics (Missiles)	L	X			
21. Stanford Research, Instru.	M		X	X	X
22. Rayco Instruments	S	X	X	X	X
23. Cutter Laboratories	M	X		X	X
24. Sandia Corporation	M		X	X	X
25. Lawrence Radiation Lab	L		X	X	X
26. American Can Company	S	X			

*Large - 5,000 or more employees. Medium - 500 to 4,999 employees Small - less than 500

RESULTS OF INTERVIEWS WITH INDUSTRIAL PERSONNEL

The Need for Technicians

Twenty-six different industrial organizations, ranging from about 50 employees to those with more than 35,000, were visited and their needs discussed. The views expressed included both personal and official viewpoints because company policies had not been formulated to cover all of the situations.

1. Virtually all of the companies studied have a very real immediate need for the electro-mechanical technician. Components and systems have become increasingly complex, to such a degree that knowledge of a single discipline is an inadequate preparation for many of the responsibilities assigned to technicians. Of the 26 firms surveyed, only four indicated no need for the electro-mechanical technician. Two of these companies employed no technicians in the divisions surveyed. Two others, both large divisions of the same company in aerospace, required electronic technicians with only minimal mechanical capabilities.
2. None of the industrial organizations included in the field study were able to recruit technicians with formal training in Electro-mechanical Technology. Graduates of these programs apparently are so few in number as to be of little significance in providing for the need. While it had been suggested by members of the Panel of Consultants that the armed forces might be good sources of electro-mechanical technicians, the survey did not reveal this to be the case. The armed forces provide a source for electronics technicians, but apparently not for those with two or more disciplines.
3. Some industrial organizations are trying to develop electro-mechanical technicians by in-plant training and evening programs. Some of the larger industries provide on-the-job training in electronics for their mechanical technicians. In most cases, however, the reverse procedure is followed: electrical or electronics technicians are given on-the-job training in the mechanical discipline. Some industries are providing chemical in-plant training courses for electro-mechanical technicians. Further study in light and optics was seen by some as a future requirement for these people.

4. Despite the great variations in size of company and type of product, there was almost unanimous agreement as to the desirable characteristics of the electro-mechanical technician and his education. Some specific characteristics were as follows:

   a. A broad technical education base is preferred to a narrow area of specialization.
   b. The fundamental principles which are inherent in all of the technologies are more important to the electro-mechanical technician than specific applications.
   c. There is a great need for the technician with more than one discipline. Either communication among individuals with different disciplines is too difficult or it is too costly, when two or more persons may be required to handle a single task. In such cases, one mechanical technician and one electronic technician may be less valuable than one electro-mechanical technician.
   d. Although it is expected that electro-mechanical technicians might want to further their education after completing their technical study, transfer credit for subjects included in the technology was not of concern. Virtually all interviewees recognized that to include any significant amount of transfer course work in the two-year curriculum could seriously weaken the program.
   e. Today, limitations on the progress of technicians in an industrial situation are likely to be self-imposed, principally by individual interests and capabilities. For those technicians with outstanding abilities, opportunities exist as specialists or consultants within their own groups. From this it was apparent that the competent technician is not on a dead-end route. Instead he is eagerly sought to fill responsible, well-paid jobs.

Educational Requirements for the Electro-mechanical Technician

During the course of the interviews, Professor Fribance probed for information and attitudes regarding the skill and knowledge required in industrial occupations of the type under consideration. Here again, no attempt was made to obtain a set of answers to a rigidly structured information form. Rather, it was thought more important, at this stage, to rely on the background experience of the researcher in curriculum planning and technical teaching to interpret and record responses as objectively as possible. The principal advantage of this procedure appeared to be in establishing rapport with the industrial representatives involved. Also, it conserved valuable time, an important consideration when busy administrative personnel were contributing to the study. To further insure accuracy in reporting, a portable tape recorder was used wherever security regulations would permit.

From the material recorded in the industrial interviews, the following observations were made regarding the educational program for electro-mechanical technicians:

1. There was almost universal agreement that the basic or core subjects on which the greatest stress should be placed are:
    a. Physics--of the applied type (should not be classical physics)
    b. Mathematics--through applied calculus
    c. Communications--drafting, sketching, composition, report writing. The ability to communicate was mentioned more frequently than was technical competency.
    d. Industrial Electronics--Regardless of the area in which the technician might be working, a good working knowledge of electronic devices, circuits, instruments, and systems is required.
2. The program should also include material in:
    a. Light and optics
    b. High vacuum techniques
    c. Engineering materials and stress analysis
    d. Chemistry, particularly from the viewpoint of corrosion
    e. Economics--as applied to industrial situations in design and application
    f. Mechanisms and basics of mechanical design
    g. Transducers for various types of instrumentation
    h. Controllers and industrial control
    i. Fundamentals of computers
3. Keen, accurate observation is greatly desired. By carefully observing, the technician should be able to analyze and synthesize. While these two abilities may not be taught in any formal courses, they should be developed in all laboratory and classroom activities. Competence in these areas may be more important than mere technical ability.
4. Certain manual skills with basic tools are important.
5. If practical, the program should not exceed two years in length.

RESULTS OF THE MAILED QUESTIONNAIRE

A two-page questionnaire with a covering letter and an Electro-mechanical Technology Curriculum (see Appendix D) was sent to 146 organizations thought to employ technicians. A total of 93 replies were returned by August 31, 1966. A summary of the responses to this questionnaire is shown in Table II. A list of the organizations is included as Appendix E of this report. The organizations responding employ a total of 36,969 technicians who work with both electrical and mechanical devices and systems.

The distribution of industries and organizations to which the questionnaire was sent was nationwide. Selection was made by the members of the Panel of Consultants. The procedure for mailing was interesting, in that all questionnaires were forwarded by members of the Panel. The preponderance of manufacturing (64 percent of all returns) reflects the influence of the panel members and their concern for this area of industrial activity. Tables III through VII show a breakdown of responses by types of industrial organizations. Table III lists the responses of 60 industries engaged in manufacturing, which was the largest group covered by the survey, employing 34,303 technicians in activities that include both electrical and mechanical devices and/or systems.

The 93 organizations employing technicians in electro-mechanical work indicated that a high percentage of their technicians have pre-employment training in electronics. Approximately 87 percent of all technicians were in this category. Those whose pre-employment training was largely mechanical made up eight percent of the group with the remaining five percent having other backgrounds.

Eighty-five of the 93 reporting organizations indicated a definite need for technicians with pre-employment training in combined electrical and mechanical principles. Four of the total employed only electronics technicians, three employed only mechanical technicians, and one did not employ graduates of two-year technical programs.

The organizations were asked to project their need for additional technicians by 1970 in order to obtain a measure of the relative employment opportunities for electro-mechanical technicians in the future, as compared with the projected need for the more conventionally trained electronics and mechanical technicians. Their need for new employees with electro-mechanical training was expected to be 5,820 in 1967, and to reach a total of 20,329 by 1970. These totals were greater by approximately 25% than their combined need for electronics technicians and mechanical technicians for the same periods.

A section of the questionnaire requested comments on:

1. Problems of providing supplementary training for technicians.
2. Job descriptions for electro-mechanical technicians.

3. The content and organization of the proposed curriculum.
4. Useful training devices for laboratory instruction.

A number of comments were obtained regarding each of the above items and these comments are included in Appendix D.

In general, the major problems encountered in providing supplementary training for technicians were reported to be problems of time and facilities. A number of respondents expressed the hope that pre-employment training for technicians in the future would include both electrical and mechanical principles.

Only 19 of the 93 industrial organizations had developed formal job descriptions for electro-mechanical technician occupations. Several others indicated a need for such descriptions.

Comments on the proposed curriculum for Electro-mechanical Technology were generally favorable. Several suggestions were made regarding changes in emphasis in specific subject matter areas.

A number of suggestions were made for laboratory devices and equipment that would be useful in the training program.

TABLE II

EMPLOYMENT AND PROJECTED NEEDS FOR TECHNICIANS IN 93 INDUSTRIAL ORGANIZATIONS

Organizations by Principal Product or Activity	Number of Responses	No. of Technicians* with Specialized Training				Projected Needs for Technicians (New Hires)					
						Electronics		Mechanical		Electro-mech.	
		Total	Electrial	Mechanical	Other	1967	1970	1967	1970	1967	1970
Manufacturing	60	34,303	30,351	2,552	1,400	2,944	10,301	840	2,530	4,666	18,478
Research & Devel	14	973	405	280	288	87	131	64	113	77	177
Design	3	111	76	33	2	4	4	5	5	13	19
Calibration & Test	12	1,501	1,176	214	111	62	102	26	56	1,060	1,652
Other	4	81	15	41	25	1	3	7	15	4	3
Total	93	36,969	32,023	3,120	1,826	3,098	10,541	942	2,719	5,820	20,329

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE III

Manufacturing

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
1. Lamp Mfg. Equipment	5	1	4	0	1	3	4	10		7
2. Petro-Chemical Mfg.	36	4	4	28	2	6	2	4	0	0
3. Mfg. of Business Machines	27000	25380	810	810	1000	4000	100	750	3100	14250
4. Mil Elec.-Mech. Systems & Comp.	19	16	1	2	12	22	0	0	6	11
5. Gas & Water Meters	34	7	27	0	5	20	4	20	8	35
6. Mfg. of Controls & Inst.	6	2	3	1	1	3	2	6	3	9
7. Mfg. of Heavy Equip. & Diesel Engineering	40	32	7	1	5	10	20	25	1	1
8. Semi conductors	700	343	350	7	50	120	50	120	10	70
9. Refining & Smelting	10	6	4	0	2	5	2	2	2	5
10. Diversified Mech. & Elec. Production	90	67	21	2	35	100	12	36	15	45
11. Natural Gas Process	3	3	0	0	1	2	1	2	2	3

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE III

Manufacturing
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians(New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
12. Refined Petro. Products	12	2	6	4			1	3	2	6
13. Communications Mfg.	300	210	60	30	100	300	100	300	100	300
14. Metal Container Mfg.	6	0	6	0	0	0	0	0	2	6
15. Photographic Equipment	75	37	38	0	10	30	15	40	20	50
16. Roller Bearings	0	0	0	0	0		0		0	
17. Aluminum	0	0	0	0	3	6	3	6	6	10
18. Semiconductor Products	400	240	160	0	700	3000	100	200	300	600
19. Photographic and Chemicals	60	27	27	6						
20. Communication Services	10	5	5	0	10	10			5	5
21. Numerically Controlled Mach. Centers	75	64	7	4	15	35	2	10	5	15
22. Military Electronics	75	30	37	8	25	50	15	25	20	40
23. Refrigeration	65	23	42	0	3	5	5	7	8	12

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE III

Manufacturing
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
24. Machine Tools	12	3	8	1	2	6	1	3	2	6
25. Fluorescent Lamps	3	3	0	0					4	7
26. Electrical Machinery	53	16	8	29	15	25	3	10	15	25
27. Flexible Packaging	10	6	2	2	3	6	5	15	7	21
28. Aircraft-Spacecraft	1200	768	156	276	110	285	55	145	190	505
29. Electronic Components	500	200	200	100	200	300	100	300	300	600
30. Mfg. of Aircraft	300	279	21	0	30	230	0	0	102	435
31. Contract Support Services	40	8	24	8	20	60	15	45	10	30
32. Petroleum Refining										
33. Mfg. of Corn Starch & Corn Sugar	9	7	2	0	2	4			2	4
34. Defense Elect. Equip.	352	348	4	0	115	470	5	25	10	50
35. Service	100	60	30	10	50	125	20	60	20	60

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE III

Manufacturing
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-Mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
36. Oil Well Drilling Tools	0	0	0	0	0	0	0	0	0	0
37. Weapons Systems	95	28	29	38	5	10	5	10	10	20
38. Aircraft Radio Equip.	50	40	10	0	25	50	5	5	10	10
39. Industrial Control Instruments	50	33	10	7	15	30	10	20	5	20
40. Computers	1600	1440	160	0	61	220			123	440
41. Tape Recorders	10	7	3	0	2	5	2	5	5	15
42. Power Supplies & Transformers	6	5	1	0	2	20	0	0	0	2
43. Aircraft	170	127	43	0	50	200	5	20	20	75
44. Construction Equipment	13	3	10	0	1	1	1	2	1	2
45. Laundry Equipment	26	9	17	0	3	5	10	15	13	20
46. Bakery	10	4	6	0	5	10	20	40	10	40

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE III

Manufacturing
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
47. Feed & Cereal Milling	5	1	4	0	2	4	2	5	2	4
48. Food Processing	21	15	6	0	6	5	4	4	7	7
48B Food Processing	22	9	11	2	13	20	23	20	20	15
49. Gear Products	15	3	12	0	1	3	15	30	3	6
50. Bearings & Manufacturing Equipment	3	0	3	0	1	5	9	15	1	3
51. Electronic Equipment	20	16	4	0	75	100	12	20	20	30
52. Unusuable										
53. Telephone Com. Products	30	27	0	3						
54. Information System	60	48	12	0					30	140
55. Microwave Tubes	275	192	69	14	75	300	30	100	50	300
56. Mfg. Elect. Component Instruments	10	7	2	1	3	10			1	5

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE III

Manufacturing
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
57. Control Mfg.	100	75	25	0	30	30	25	30	30	40
58. Telephone Mfg.	50	37	13	0	45	35	20	20	28	60
59. Food Mfg.	2	1	1	0	0	0	0	0	1	1
60. Photographic & Chem.	60	27	27	6						
Total	34303	30351	2552	1400	2944	10301	840	2530	4666	18478

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE IV

Research & Development

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
1. Engineering Research	6	2	3	1	10	20	20	40	3	10
2. Contract Research	6	5	1	0	1	3	0	2	1	2
3. Research in Mfg. of Chem.	12	4	4	4	2	3	2	3	1	2
4. Research	50	45	5	0	30		6		2	
5. Aerospace	12	2	2	8	0	0	0	0	2	10
6. Shaft Encoders	5	2	2	1	1	4	1	4	2	8
7. Consulting	2	1	1	0			2	4	1	5
8. Broad Spectrum of Engineering	18	3	13	2	1		10		10	
9. Nuclear Sciences	700	301	224	175	10	30	5	15	25	75
10. Research & Engineering	32	11	8	13	2	6	3	9	3	5
11. Research & Development	3	2	1	0	8	10	1	1	5	10

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE IV

Research & Development
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
12. Materials Research	57	9	8	40	2	5	2	5	5	20
13. Solar Observatory	20	15	3	2	10	20	5	10	5	10
14. Manned - Space Research	50	3	5	42	10	30	7	20	12	20
Total	973	405	280	288	87	131	64	113	77	177

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE V

Design

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
1. Wave Filters	4	2	2	0					2	8
2. Nuclear Ord. Hdw.	95	67	28	0	2	2	2	2	8	8
3. Design of New Facilities	12	7	3	2	2	2	3	3	3	3
Total	111	76	33	2	4	4	5	5	13	19

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE VI

Calibration & Test

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
71. Ordance Engineering	12	9	2	1					4	5
72. Electro-Optical Instr.	17	14	0	3					4	4
73. Data Acquisition Inst.	25	24	1	0	4	16	1	10	5	20
74. Rad., T.V., & Special Instruments	12	8	4	0	20	30	5	7	5	10
75. Electric Utility	13	0	0	13	4	6	3	7	7	12
76. Elect. Digital Computer	1000	900	100	0	0	0	0	0	1000	1500
77. Weighing Devices & Systems	6	5	1	0	6	15	2	6	0	0
78. Evaluation of Oil Bearing Formation	30	5	0	25	15	15	0	0	0	0
79. Analytical Instrument	20	6	8	6			3	10	5	15
80. Radiation Measurement Instruments	50	45	5	0					15	60

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE VI

Calibration & Test
(Continued)

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronic		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
81. Utilities	300	150	90	60	10	10	10	10	10	10
82. Space Instrumentation	16	10	3	3	3	10	2	6	5	16
Total	1501	1176	214	111	62	102	26	56	1060	1652

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

TABLE VII

Other

Organizations by Principal Product or Activity	No. of Technicians* with Specialized Training				Proposed Needs for Technicians (New Hires)					
					Electronics		Mechanical		Electro-mechanical	
	Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
1. Management Consultant	1	1	0	0	0	0	0	0	0	0
2. Intravenous Injection	1	0	1	0	0	3	2	5	1	3
3. Inst. Repair	5	4	0	1	1		1		3	
4. Food & Manufacturing	74	10	40	24	0	0	4	10	0	0
Total	81	15	41	25	1	3	7	15	4	3

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

Electromechanical Technology

SUMMARY AND CONCLUSIONS

The field study fo electro-mechanical technician occupation was conducted in two stages. In the first phase of the study, personal interviews were conducted in 26 industrial organizations selected by size and by principal activity and distributed geographically throughout the United States.

Twenty-two of the 26 organizations included in this phase of the study indicated an expanding need for technicians capable of working with electro-mechanical systems and devices. At the time the study was conducted these 22 firms employed electronics technicians or mechanical technicians and provided on-the-job training in electronics or mechanics correspondent to individual needs. All of the 22 saw a pressing need for pre-employment training of technical personnel for these occupations. The kind of pre-employment training desired was described as follows:

1. The training should put emphasis on electrical and mechanical principles rather than on specific applications of these principles.
2. Communication skills are extremely important in the work of electro-mechanical technicians and should be given special attention in the training program.
3. A study of the interrelationship of electrical and mechanical elements of systems and devices should be central in the specialized technical courses of the instructional program. Whenever possible electrical and mechanical principles should be studied together, and not as separate entities.
4. Principles of electrical and mechanical physics are basic tools in the work of electro-mechanical technicians and all technical instruction should develop analytical skills for which these tools are fundamental. In addition, there is an increasing need for the technician to work with new applications of other physical sciences such as: optical equipment, thermal energy devices, hydraulic and pneumatic controls, and a wide variety of measuring instruments.

The second phase of the study utilized a very brief questionnaire designed to obtain a broad sample of the quantitative need for electro-mechanical technicians. Ninety-three industrial organizations responded to the request for information. Their total need for trained electro-mechanical technicians (new hires) was estimated to be 20,329 by 1970, a number 25% greater during this period than their combined hires of electronic technicians and mechanical technicians.

The use of a personal interview technique in this study made it mandatory to select an individual with special qualifications. The principal consultant on this project was especially well-qualified, having had recent experience in engineering and technical institute teaching, curriculum design in two-year technology programs, and field work in a national study of instrumentation education programs.

In general, the study succeeded in its major objectives of identifying occupational and educational needs in the new and emerging occupation of electro-mechanical technology. The information obtained has been used to prepare a basic curriculum plan for a two-year, post-high school program in electro-mechanical technology. This curriculum plan, with recommendations for developing instructional materials and laboratory facilities, will be prepared and submitted as a separate report to the U.S. Office of Education.

The results of the study indicate a clear and pressing need for experimentation and innovation in the development of technical education for new and emerging occupations. The evidence points to a specific need for new training programs in electro-mechanical technology and suggests that similar combinations of technological skills may be required in other emerging occupations.

Experimentation and innovation is indicated because of the need for an interdisciplinary training approach that apparently does not now exist or, if it exists, has not been documented. While the field study did not include educational institutions and programs, and hence did not provide conclusive evidence as to the educational processes involved, there was a general feeling that more is needed in the training of electro-mechanical specialist than a simple combination of existing courses in electrical technology and mechanical technology.

The procedures used in the field study were somewhat unconventional, in that a great deal of the information obtained required subjective value judgments on the part of the principle consultant. This procedure appears to be justifiable when no taxonomy exists for the kind of rigidly structured survey instruments that might normally be used. The controls in this case rested with the Panel of Consultants who, in a sense, served as a jury of experts. As educational programs for this emerging occupation are developed, more sophisticated analyses will be required to better identify sepcific job functions.

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APPENDIX A

PANEL OF CONSULTANTS
ELECTRO-MECHANICAL RESEARCH STUDY
1965-66

Ted Boaz, Director
Technical-Vocational Education
Del Mar Technical Institute
Corpus Christi, Texas

Roger W. Bolz
Editor-in-Chief
AUTOMATION
Cleveland, Ohio

Gordon L. Bratt
Technical and Vocational
Training Branch
Department of Labour
Ottawa, Ontario, Canada

J. E. Casey
Leeds & Northrup
Bryn Mawr, Pennsylvania

Edward Broghamer
Department of General Engineering
University of Illinois
Urbana, Illinois

C. E. McNeil
International Business
Machines Corporation
Armounk, New York

Malcom Easterday
Department Supervisor
Test Equipment
The Bendix Corporation
Kansas City, Missouri

Charles Merritt
Consolidated Electrodynamics Corp.
Pasadena, California

Joseph J. Gershon
Dean of the Resident School
DeVry Technical Institute
Chicago, Illinois

Joseph A. Patterson
Texas Instruments Inc.
Semiconductor-Components Division
Dallas, Texas

John C. New, Chief
Test and Evaluation Division
Goddard Space Flight Center
Greenbelt, Maryland

E. Mark Sheldon, Manager
of Instruction
Control Data Institute
Minneapolis, Minnesota

Burton K. Snyder, Chief Engineer
Central Shops
Argonne National Laboratories
Argonne, Illinois

APPENDIX B

DEFINITIONS

Technician

An engineering technician is one whose education and experience qualify him to work in the field of engineering technology. He differs from a craftsman in his knowledge of scientific and engineering theory and methods and from an engineer in his more specialized background and in his use of technical skills in support of engineering activities.[1]

To aid in identifying occupations which require technical education, the Vocational-Technical Division of the United States Office of Education has developed a list of occupational criteria.

It is necessary to have a reference base for applying these criteria if they are to be useful in developing educational programs. The reference base to be used with the criteria consists of five general abilitites.

General Abilities[2]

1. Facility with mathematics; ability to use algebra and trigonometry as tools in the development of ideas that make use of scientific and engineering principles; an understanding of, though not necessarily facility with, higher mathematics through analytical geometry, calculus, and differential equations, according to the requirements of the technology.

2. Proficiency in the application of physical science principles, including the basic concepts and laws of physics and chemistry that are pertinent to the individual's field of technology.

3. An understanding of the materials and processes commonly used in the technology.

4. An extensive knowledge of a field of specialization with an understanding of the engineering and scientific activities that distinguish the technology of the field. The degree of competency and the depth of understanding should be sufficient to enable the individual to do such work as detail design using established design procedures.

5. Communication skills that include the ability to interpret, analyze, and transmit facts and ideas graphically, orally, and in writing.

In applying each criteria the five general abilities must be considered basic and corporate. No single criteria can be considered as definitive unless the level of competence being exercised is within the framework established by these five ability requirements.

The Individual in the Occupation.[3]

1. Applies knowledge of science and mathematics extensively in rendering direct technical assistance to scientists or engineers engaged in scientific research and experimentation.
2. Designs, develops, or plans modifications of new products and processes under the supervision of engineering personnel in applied engineering research, design, and development.
3. Plans and inspects the installation of complex equipment and control systems.
4. Advises regarding the maintenance and repair of complex equipment with extensive control systems.
5. Plans production as a member of the management unit responsible for efficient use of manpower, materials, and machines in mass production.
6. Advises, plans, and estimates costs as a field representative of a manufacturer or distributor of technical equipment and/or products.
7. Is responsible for performance of environmental tests of mechanical, hydraulic, pneumatic, electrical, or electronic components or systems and the preparation of appropriate technical reports covering the tests.
8. Prepares or interprets engineering drawings and sketches.
9. Selects, compiles, and uses technical information from references such as engineering standards, handbooks, and technical digests of research findings.
10. Analyzes and interprets information obtained from precision measuring and recording instruments and makes evaluation upon which technical decisions are based.
11. Analyzes and diagnoses technical problems that involve dependent decisions.

12. Deals with a variety of technical problems involving many factors and variables which require an understanding of several technical fields.

Engineering Technology

Engineering technology is that part of the engineering field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational area between the craftsman and the engineer.[4]

Engineering Technology Curriculum

An engineering technology curriculum is a planned sequence of college-level courses, usually leading to an associate degree, designed to prepare students to work in the field of engineering technology.[5]

(a) The term college-level in the definition of a technology curriculum indicates the attitude with which the education is approached, the rigor, and the degree of achievement demanded, and not solely or even necessarily that the credits are transferable to baccalaureate programs.

(b) There are many specific branches of engineering technology in which curricula are offered. Commonly encountered are such curriculum titles as mechanical technology, electronic technology, chemical technology, and civil technology.

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APPENDIX C

LIST OF 55 ORGANIZATIONS SELECTED FOR FIELD INTERVIEWS

NEW YORK and PENNSYLVANIA and NEW JERSEY

	COMPANY	ADDRESS
1.	Xerox Corporation	Rochester, New York
2.	Kodak	Rochester, New York
3.	General RR Signals	Rochester, New York
4.	Bethleham Steel	Buffalo, New York
5.	American Can	Geneva, New York
6.	General Electric	Schenectady, New York
7.	I. B. M.	Armounk, New York Binghampton, New York
8.	Otis	New York City, N. Y.
9.	Bell Laboratories	New Jersey
10.	Campbell's Soup Co.	New Jersey
11.	Westinghouse	Pittsburg, Penn.
12.	Pittsburg Plate	Pittsburg, Penn.
13.	U. S. Steel	Pittsburg, Penn.

MID UNITED STATES

	COMPANY	ADDRESS
1.	Control Data	Minneapolis, Minn.
2.	Honeywell	Minneapolis, Minn.
3.	3-M Company	Minneapolis, Minn.
4.	Argonne Labs.	Chigaco, Illinois
5.	Illinois Institute of Technology	Chicago, Illinois
6.	Abbot Labs.	Chicago, Illinois
7.	Western Electric	Chicago, Illinois
8.	Bell & Howell	Chicago, Illinois
9.	G. M. Research	Michigan
10.	Dow Chemical Michigan	Michigan
11.	Whirlpool	Michigan
12.	American Electric Power	Canton, Ohio
13.	Cincinnati Milling	Cincinnati
14.	Goodyear Tire & Rubber Co.	Akron, Ohio
15.	General Electric	Louisville, Ky.
16.	I. B. M.	Louisville, Ky.
17.	McDonnell Aircraft	St. Louis, Mo.
18.	Ralston Purina	St. Louis, Mo.
19.	American Airlines	Tulsa, Oklahoma
20.	Texas Instruments	Dallas, Texas
21.	General Dynamics	Dallas, Texas
22.	Ling Temco	Dallas, Texas

NEW ENGLAND

COMPANY	ADDRESS
1. Sylvania	Boston, Mass.
2. Gillette	Boston, Mass.
3. R. R. Donnelly	Sagbrook, Conn.
4. Groton-Electric Boat	Groton, Conn.

MIDDLE ATLANTIC

COMPANY	ADDRESS
1. DuPont	Delaware
2. Goddard	Maryland
3. Western Electric	North Carolina
4. Burlington Industries (Textile)	North Carolina
5. American Tobacco	North Carolina

WEST

COMPANY	ADDRESS
1. Motorola	Phoenix, Arizona
2. General Electric	Phoenix, Arizona
3. C.E.C.	Los Angeles, California
4. S.R.I.	Stanford, California
5. Lockheed	Sunnyvale
6. Lawrence Rad. Labs	Palo Alto, California
7. Ames Research	Palo Alto and Stanford, Calif.
8. Sandia	Palo Alto, Calif.
9. Weyerhauser	Oly, Wash.
10. Boeing Aircraft Co.	Seattle, Wash.

SOUTHEAST

COMPANY	ADDRESS
1. Pan American	Cape Kennedy, Fla.

APPENDIX D

Materials For Mail Survey of Employment Needs

Joseph A. Patterson
Texas Instruments, Inc.
Semiconductor-Components Division
13500 North Central Expressway
Dallas, Texas 75222

Dear Mr. Patterson:

Under the terms of a contract with the United States Office of Education, Oklahoma State University is carrying on a research study to determine:

1. If there is a significant requirement in American industry for a technician with combined educational experiences in both the electrical (electronic) and the mechanical disciplines.
2. If such technicians are required, what would be a desirable post-high school curriculum for an Electro-Mechanical Technologist.

The first phase of this research has been completed. A field study of 26 major employers, conducted by personal interviews, has identified a real need for electro-mechanical technicians. It is desirable now to obtain a broader sampling of this need.

If you employ technicians with 2-year post-high school technical training, it would be most helpful to us if you would respond to the questions on the enclosed form and return your comments to us at the Oklahoma State University.

A proposed curriculum in Electro-Mechanical Technology has been developed, based on information obtained from the field study. A copy of this curriculum is enclosed. Any comments you may have with respect to content and organization of this study program will be helpful. This curriculum plan will be developed further and in its final form will be given national distribution to encourage the development of programs.

Please feel free to duplicate this material for the reactions of others if you care to do so. Your time and effort in assisting with this study is appreciated.

Sincerely,

Maurice W. Roney
Project Director
Electro-Mechanical Study

INFORMATION ON THE NEED FOR ELECTRO-MECHANICAL TECHNICIANS

The following questions pertain to technical personnel whose duties and responsibilities involve work with both electrical (electronics) and mechanical devices and systems. We are concerned with activities which require pre-employment education and training beyond high school but less than the baccalaureate degree.

Responses to these questions will not be identified with persons or organization in any published materials or reports.

1. Name of Company or Division ____________________

   Principal Product or Activity ____________________

   Name of Individual Reporting ____________________

2. How many technicians in your organization currently work with both electrical (electronics) and mechanical devices and/or systems:

   ____
   (Number)

3. What is the approximate percentage distribution of these technicians who have pre-employment training in only one of these specialized fields:

   a. Electronic technology ____________________
   (Approximate Percentage)

   b. Mechanical technology ____________________
   (Approximate Percentage)

   c. Other __________ ____________________
   (Approximate Percentage)

4. Do you have or do you anticipate a specific need for technicians with pre-employment training which combines electrical and mechanical principles?

   ____

   ____

5. If persons with the combination of electrical-electronic and mechanical training become available, (see enclosed curriculum for a description of the training) what do you expect your need might be in the future in the following areas.

Number of electronics technicians needed (New Hires) ______ in 1967 ______ in 1970

Number of mechanical technicians needed (New Hires) ______ in 1967 ______ in 1970

Number of electro-mechanical technicians (New Hires) ______ in 1967 ______ in 1970

In addition to the foregoing quantitative information, any comments you may have on the following will be helpful:

6. Have you encountered specific problems in providing supplemental training for electro-mechanical technicians whose pre-employment training has been limited to only one of the two fields.

7. Have you developed job descriptions which indicate the functions and responsibilities of electro-mechanical technicians.

8. Does the content and organization of the proposed curriculum (enclosed) appear to be suitable for the purpose of preparing electro-mechanical technicians.

9. Do you have suggestions for electro-mechanical devices and/or systems that would be useful in the training program to illustrate applications of basic principles.

Please Return to:

Electro-Mechanical Research Project
Room 104, Industrial Building
Oklahoma State University
Stillwater, Oklahoma 74074

ELECTRO-MECHANICAL TECHNOLOGY CURRICULUM

REVISED AS OF APRIL 26, 1966

	ELECTRICAL ELECTRONIC COURSES	MECHANICAL COURSES	ELECTRO-MECHANICAL COURSES*	PHYSICS & AUXILIARY COURSES	MATH & GENERAL EDUCATION COURSES	
	CLASS 3 LAB 4 CR. 4	CLASS 1 LAB 3 CR. 2	CLASS 1 LAB 3 CR. 2	CLASS 3 LAB 2 CR. 4	CLASS 5 CR. 5	CLASS 1 CR. 1
1st TERM	ATOMIC AND MOLECULAR STRUCTURE (CONDUCTORS, SEMI-CONDUCTORS) BASIC ELECTRICAL UNITS D. C. CIRCUITS A. C. CIRCUITS	USE OF HAND TOOLS FITS AND FINISHES THREADS AND FASTENERS MACHINES AND MACHINE PROCESSES	MECHANICAL COMPONENTS AND INTRODUCTION TO ELECTRO-MECHANICAL SYSTEMS	TIME AND SPACE UNITS BASIC ENERGY SYSTEMS MECHANICS (STATICS, DYNAMICS) MECHANICAL MEASUREMENTS -- TEMPERATURE, PRESSURE	REVIEW OF INTERMEDIATE ALGEBRA TRIGONOMETRY ADVANCED ALGEBRA	TECHNICAL REPORT WRITING
	CLASS 3 LAB 4 CR. 4	CLASS 3 LAB 2 CR. 4	CLASS 1 LAB 2 CR. 2	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 0 CR. 3	
2nd TERM	A. C. CIRCUITS (CONTINUED) VACUUM TUBES SEMI-CONDUCTORS AND CIRCUITS POWER SUPPLIES AMPLIFIERS	MATERIALS TESTING ENGINEERING MATERIALS - METALS, TIMBER, PLASTICS SIMPLE STRUCTURES HEAT TREATMENT COMPOSITE MATERIALS	HIGH ENERGY LIGHT SYSTEMS HYDRAULIC AND PNEUMATIC DEVICES HIGH VACUUM EQUIPMENT	SOLID STATE PHYSICS PRINCIPLES OF HEAT AND HEAT TRANSFER LIGHT AND OPTICS FLUID MECHANICS	APPLICATIONS OF ANALYTIC GEOMETRY AND CALCULUS	
					OPTIONAL SUBJECTS - DEGREE REQUIREMENTS, CHEMISTRY, ETC.	
	CLASS 3 LAB 4 CR. 4	CLASS 2 LAB 6 CR. 4	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 2 CR. 4	CLASS 2 LAB 0 CR. 2	
3rd TERM	LOGIC CIRCUITS LOGIC SYSTEMS SYSTEMS ANALYSIS TIMING AND WAVE SHAPING CIRCUITS MEASURING INSTRUMENTS ELECTRICAL TRANSDUCERS	GEARS AND GEAR TRAINS PLANE MOTION DIFFERENTIAL MOTION MECHANICAL INTEGRATION TORQUE AMPLIFICATION & FORCE AMPLIFIERS CLUTCHES AND COUPLINGS BEARINGS LUBRICATION	SYNCHROS, RESOLVERS SERVO-MOTORS AND GENERATORS CHOPPERS, TACHOMETERS SERVO AMPLIFIERS HYDRAULIC SERVOS DIGITAL-ANALOG CONVERTORS TELEMETERING DEVICES RECORDERS, PLOTTERS	ELECTRICAL MOTORS AND GENERATORS SPEED CONTROL TRANSMISSIONS CLUTCHES SERVO MECHANISMS INTRODUCTION TO CLOSED LOOP SYSTEMS	NUMBER SYSTEMS LOGIC SYSTEMS BOOLEAN ALGEBRA	
		CLASS 3 LAB 3 CR. 4	CLASS 3 LAB 3 CR. 4	CLASS 1 LAB 6 CR. 3	CLASS 3 CR. 3	CLASS 3 CR. 3
4th TERM		ELECTRICAL, MECHANICAL, HYDRAULIC PROCESS CONTROLLER VARIABLE POWER DEVICES COMPUTERS CLOSED LOOP SYSTEMS	ELECTRO-MECHANICAL SYSTEMS DESIGN PRINTERS DIGITAL READOUT MISSILE CONTROL ELEVATOR CONTROL TAPE TRANSPORTS TELETYPEWRITERS DATA STORAGE & RETRIEVAL	DESIGN PROBLEM PROBLEM ANALYSIS DATA COLLECTION TECHNIQUES DATA EVALUATION TECHNIQUES PROBLEM DEFINITION PROBLEM SOLUTION(S) SOLUTION EVALUATION SOLUTION IMPLEMENTATION VERIFICATION	ECONOMICS	COMMUNICATIONS

*THE DEVICES AND SYSTEMS TO BE USED WILL BE SELECTED INDUSTRIAL APPLICATIONS.
THE ITEMS SHOWN ARE TYPICAL

ADMISSION REQUIREMENTS:
HIGH SCHOOL MATHEMATICS THROUGH TRIGONOMETRY: MECHANICAL DRAWING
A PRE-TECHNOLOGY TERM WILL BE NECESSARY FOR STUDENTS NOT MEETING THESE REQUIREMENTS.

APPENDIX E

NAMES OF 93 ORGANIZATIONS RESPONDING TO THE QUESTIONNAIRE

Manufacturing

Sylvania Electric Products Inc.
Lighting Division
Lamp Manufacturing Equipment
Salem, Mass.

Union Carbide Corp.
Petro-Chemical Manufacturer
Victoria, Texas

IBM Corporation
Manufacturer of Business Machines
Armonk, New York

American Bosch Arma Corp.
Arma Division
Military Electronic and Electro-mechanical Systems & Components
Garden City, New York

Amercon Company
Gas & Water Meters
Philadelphia, Pa.

ITT Controls & Instruments Division
Mfg. of Controls & Instruments
Glendale, California

Caterpillar Tractor Co.
Research Dept.
Mfg. Heavy Equip. & Diesel Engines
Peoria, Ill.

Motorola Inc.
Semiconductors
Franklin Park, Illinois

Barber-Colman Co.
Diversified Mech. & Elec. Prod.
Rockford, Ill.

Aluminum Company of America
Point Comfort Operations
Refining and Smelting

LaGloria Oil & Gas Co.
Natural Gas Processing Plant
Falfurrus, Texas

Southwestern Oil & Refining Co.
Refined Petroleum Products
Corpus Christi, Texas

Western Electric Co.
Communications, Manufacturing
Chicago, Ill.

Bell & Howell Co.
Photo Products Division
Photographic Equipment
Chicago, Ill.

Continental Can. Co.
Metal Container Mfg.
Houston, Texas

Timken Roller Bearing Co.
Tapered Roller Bearings
Canton, Ohio

Reynolds Metals Co.
San Patricio Plant
Virgin Aluminum
Gregory, Texas

Texas Instruments, Inc.
Semiconductor Components, Div.
Semiconductor Products
Dallas, Texas

Eastman Kodak Co.
Rochester Division
Photographic Equipment & Chemicals
Rochester, New York

The Bell Telephone Co.
Communications Services
Philadelphia, Pa.

Kearney & Trecker Corp.
Numerically Controlled Mach. Centers
Milwaukee, Wis.

LTV Electro Systems, Inc.
Garland Division
Military Electronics
Dallas, Texas

Whirlpool Corp.
Refrigeration
Evansville, Ind.

Bodine Corp.
Mach. Tools
Bridgeport, Conn.

Sylvania Electric Products Inc.
Fluorescent Lamps
Danvers, Mass.

General Railway Signal Co.
Electrical Machinery
Rochester, New York

Pollock Paper Co.
Flexible Packaging
Dallas, Texas

McDonnell Aircraft Corp.
Engineering Divisions
Aircraft - Spacecraft
St. Louis, Mo.

Sprague Elec. Co.
Electronic Components
North Adams, Mass.

General Dynamics
Fort Worth Division
Manufacture of Aircraft
Fort Worth, Texas

Sperry T&E Support Facility
Contract Support Services
Greenbelt, Maryland

Atlantic Richfield Co.
Atlantic Division
Petroleum Refining
Philadelphia, Pa.

Corn Products Co.
Mfg. of Corn Starch & Corn Sugar
Corpus Christi, Texas

Westinghouse
Defense & Space Center
Defense Electronic Equipment
Baltimore, Maryland

Honeywell, Inc.
Annapolis Operation - Service
Annapolis, Md.

Honeywell, Inc.
Industrial Division
Philadelphia, Pa.

UNIVAC
Div. of Sperry Rand Corp.
Computers
Blue Bell, Pa.

Hughes Tool Co.
Mfg. Oil Well Drilling Tools
Corpus Christi, Texas

U. S. Naval Ordinance Laboratory
Weapons Systems
Silver Spring, Md.

King Radio Corp.
Aircraft Radio Equipment
Olathe, Kansas

Genisco Technology Corporation
Tape Recorders - Instrumentation
Compton, California

EMP Electronics, Inc.
Power Supplies & Transformers
Phoenix, Arizona

Lockheed-California Company
Aircraft
Burbank, California

International Harvester Company
Construction Equipment Division
Melrose Park, Ill.

Whirlpool Corp.
Resident Laundry Group Division
Central Engineering - Applied
Benton Harbor, Michigan

Mrs. Baird's Bread Company
Bread, Rolls, Buns & Cakes
Dallas, Texas

The Quaker Oats Company
Feed and Cereal Milling
Sherman, Texas

Campbell Soup Company
Food Processing
Paris, Texas & Camden, New Jersey

Falk Corporation
Gear Products
Milwaukee, Wisconsin

The Torrington Company
Mfg. of Bearings & Mfg. Equipment
Torrington, Connecticut

Zenith Radio Corporation
Electronics Equipment
Chicago, Illinois

The Boeing Company
Aerospace Group
Seattle, Washington

Automatic Electric
Northlake, Illinois

Xerox Corporation
Rochester, New York

Varian Associates
Microwave Tubes

American Bosch Arma Corp.
Tele-Dynamics Div.
Philadelphia, Pa.

Bailey Meter Company
Mfg. of Instruments & Controls
Wickliffe, Ohio

Western Electric Company
Hawthorne Works
Chicago, Ill.

Anderson, Clayton & Co.
Edible Fats and Oils
Sherman, Texas

Eastman Kodak Co.
Photographic Equipment & Chemicals
Rochester, New York

Calibration & Test

Sandia Corp.
Test Equipment Department
Ordnance Engineering
Albuquerque, New Mexico

Royco Instruments, Inc.
Electro-Optical Instruments
Menlo Park, California

Consolidated Electrodynamics Corp.
Data Acquisition Instrumentation
Pasadena, California

Zenith Radio Corp.
Radio, TV, and Special Electronics
Chicago, Illinois

Central Power and Light Co.
Electric Utility
Corpus Christi, Texas

Honeywell Inc.
E.D.P. Division
Electronic Digital Computers
Wellesley Hills, Mass.

Toledo Scale Corp.
Weighing Devices & Systems
Toledo, Ohio

Welex-Wire Line Service Co.
Evaluation of Oil Bearing Formations
Houston, Texas

Beckman Instruments, Inc.
Process Instruments Operations
Analytical Instruments
Fullerton, California

Packard Instrument Co., Inc.
Radiation Measurement Instrumentation
Downers Grove, Ill.

Philadelphia Electric Company
Elec., Gas, and Steam
Philadelphia, Pa.

Kollsman Instrument Corporation
Space Division
Syossei, New York

Research & Development

TRW Systems
Aerospace
Redondo Beach, California

Datex
Shaft Encoders
Monrovia, California

Lessells and Associates Inc.
Consulting
Waltham, Mass.

E. I. DuPont de Nemours & Co.
Broad Spectrum of Engineering
Wilmington, Delaware

Brookhaven Nat'l Laboratory
Basic Research in the Nuclear Sciences
Upton, New Jersey

Whirlpool Corporation
Research Laboratories
Benton Harbor, Michigan

Stanford Research Institute
Engineering Sciences Area
Menlo Park, California

National Bureau of Standards
Institute for Materials Research
Washington, D. C.

Ball Brothers Res. Corp.
Orbiting Solar Observatories
Boulder, Colorado

NASA
Space-Manned Research

FMC Corp.
Central Engineering Labs
Research & Development
Santa Clara, California

Midwest Research Institute
Contract Research and Development
Kansas City, Missouri

Celanese Chemical Co.
Technical Center
Houston, Texas

RCA Laboratories
Research
Princeton, N. J.

Design

Dietz Design, Inc.
Wave Filters
Kansas City, Mo.

Sandia Corp.
Nuclear Ordnance Hardware
Livermore, California

Proctor & Gamble
Engineering Division
Central Engineering Design
Cincinnati, Ohio

Other

Dasol Corp.
Management Consultants
New York, New York

Cutter Laboratories
Intravenous Solutions & Injection
Equipment
Berkeley, California

Lee Asso. Inc.
Sales Rep.
Orlando, Florida

Kraft Foods Company
Food Mfg.
Garland, Texas

APPENDIX F

Responses to General Questions 6, 7, 8, and 9 on the Questionnaire

6. Have you encountered specific problems in providing supplemental training for electro-mechanical technicians whose pre-employment training has been limited to only one of the two fields?

Our basic problems have been time to teach and the teaching skills necessary.

Not specifically - but have detected a lack of mechanical interest by typical "electroniker."

No - If the training were electronic.

Generally we have found it to be easier to train an electronics technician in the mechanical area than vice-versa.

We have had difficulty in training Electro-mechanical Technicians for very basic mechanical principles.

No - The RCA Laboratories is a large research organization employing over 200 Research Technicians, many of whom are electronics in training (i.e., RCA Institutes). Mechanical skills to any degree are supplied by mechanically trained Model Makers in our Main Shop.

No, but on-the-job training is difficult and expensive. Would prefer to avoid by hiring capable personnel.

We do some formal cross training.

No specific training undertaken.

Yes - Technicians trained in mechanical systems to grasp electronic systems.

No specific problems.

The main problem is the time and manpower required to do the training.

The majority of our technicians have completed the electronic technology curriculum and considerable time and money must be expended in OJT in the mechanical areas.

Only that we would prefer to have them educated in the cross discipline before being hired so that we can be an industry rather than a training institute.

The training requires three-five years of "on-the-job" experience.

No, use of Industrial Arts high school and on job training to broaden base in other field.

Cross training.

Yes, we tend to reinforce the specialty.

Some reluctance to go back to the books.

Generally "Electronic" Techs tend to look down their nose at mechanical problems.

In some locations, due to lack of educational facility, it has been impossible except by in-plant programs that only skim the total subject need.

A large majority of the personnel we hire are well oriented in electronics, but have a limited background in electro-mechanical devices. It is in this area where we require more extensive detailed training than would normally be necessary, if backgrounds were equally balanced in electronics and electro-mechanics.

Yes - We institute specific training programs to qualify our employees.

Usually a fear of becoming jack-of-all trades, master of none. Electronics seems to be more "romantic". It's easier to get a mechaniker to absorb electronic training than vice versa.

Yes - In general they do not have the basis to learn the other.

Yes - (1) Quality of area electronic circuitry courses in Junior College.
(2) Difficult to develop techs. by moving them to other areas if they aren't ready.

We have had to set up our own with outside help.

It has been necessary on frequent occasions to provide supplemental training for technicians trained in only one field. This is particularly common in providing electronics technicians with mechanical training.

We have no problems in providing supplemental training. Our "in house" courses are adequate.

We have not encountered any specific problems in providing supplementary training, but we do find it takes a full time training program of a month or more duration. We find it easier to teach the Elec. Technicians those requirements in the Mech. Tech. than the reverse. As a result, we have been hiring predominately electrically or electronically trained technicians for the last 10 yrs., choosing to train them in the required mechanical areas.

Most of the technicians are used either electrically or mechanically with, of course, some functional overlapping. The extent to which the two disciplines overlap presents no particular training problem.

Greatest need is electrical training for mechanical technicians. Especially needed is exposure to various types of electrical instrumentation.

7. Have you developed job descriptions which indicate the functions and responsibilities of electro-mechanical technicians?

We have not come up with other than very rough job descriptions for these people.

No, small size of our company does not require formal documentation of this type.

No, the descriptions are more specific - some may be equivalent.

Will probably do so in 1966 or 1967.

No, but we have made some studies.

Not specifically - We are using two separate job descriptions.

Yes, generalized job description for Development Technicians.

No, positions are varied.

No, we do not as yet have formal job descriptions even of our present technicians.

We do not have specific job descriptions for Electro-Mechanical Technicians, as their job requirements are over-all in the electronics and Electro-Mechanical areas.

These job descriptions remain fluid. There is a tendency to drop "mechanical technician" and end up with Electronic Tech, Electro-Mech Tech, and model maker or machinist.

Only as to employee rates.

Yes, e.g., Electronic-Mechanical Technician, Inspector Electrical-Mech., Inspector Electronic-Mechanical, Pilotless Aircraft, Radio Electronic-Mechanical Technician.

We have developed job descriptions for these technicians. These are coordinated with our Personnel Office to assure that we properly follow Civil Service regulations.

We do have different job descriptions covering Mech., Elec. and other Technicians but the levels of salary and responsibility are identical.

We have not developed a specific job description for an electro-mechanical technician. This job description is included in our engineering associate classification.

8. Does the content and organization of the proposed curriculum (enclosed) appear to be suitable for the purpose of preparing electro-mechanical technicians?

(a) Courses generally appear suitable.
(b) Vacuum tubes almost totally obsolete in our business.
(c) Instrumentation courses on measurements such as temperature, vibration, acceleration and pressure would be useful.
(d) The courses don't seem to include enough math as a requirement unless the math and G. E. courses are a required part of E. E. and M. E. curriculum.
(e) Electrical-electronic courses appear rather short. Suggest an additional term. Motor theory is missing.
(f) Mechanical courses do not appear to cover enough needed precision mechanical measurement theory and training. A complete curriculum in mechanical measurements would be very valuable. We are unable to find people with this training.

Yes - perhaps more stress on the physics of processes used in high vacuum systems would be valuable.

Excellent except as noted - We feel that no technological curriculum for the purpose of preparing industrial employees should be without comprehensive education in the science and technology of person to person communication and personal relationships.

In our estimation a general knowledge of chemistry similar to that obtained in a first class high school chemistry course would be a requirement of the first order in the education of an industrial technician.

There are some highly specialized items in the proposed curriculum which we would consider of much less general desirability than the understanding of radio frequency and pulse techniques. We are, of course, not sure that this material is not contemplated in some of the proposed courses.

Your proposed electro-mechanical curriculum appears to include all the areas of learning necessary to adequately train Electro-mechanical technicians. We would recommend that you stress, whenever possible, the practical application of electro-mechanical devices as opposed to the theoretical application.

The content of the enclosed appears quite suitable for the purpose of preparing electro-mechanical men.

The courses should include mechanical drawing and design principles and techniques.

Suggest greater emphasis on fundamentals.

Very suitable.

The proposed electro-mechanical curriculum should produce a well qualified technician for our industry.

Yes although this industry has little need for E. M. Technical.

The training would appear to cover two types of jobs:
- (1) Technical, that might be used in product testing or quality control of an intricate product, very "low grade" design or research, minor engineering jobs, etc.
- (2) Certain EDP jobs.

I strongly recommend "shop training" in machining, fitting, welding, brazing, soldering, wiring, gauging, etc.

It is excellent.

Only suggestion is greater depth on "Report Writing". This is a time consuming and expensive program to view in-plant.

Appears to be adequate for most needs; would prefer to see more emphasis on Optics because of our needs.

Packaging Machinery people feel that "logic systems" should be required not optional.
Electrical Engineers feel content "OK".
Process Control and Instrumentation people feel that a course such as:
- (1) Basic Instrumentation and Control.
- (2) Basic Chemistry
- (3) More time for report writing should be included.

They would be willing to sacrifice some electronics and much mechanical subject matter for this.

In order to adequately train technicians for the maintenance of Data Processing equipment, the students should have actual "hands on" experience on Computer Electrical Mechanical Equipment such as, Magnetic Tape Handlers; Card Handling Equipment such as, Punches, Readers, Sorters, etc.

Students should be exposed to actual equipment in Technical Schools to learn the basic fundamentals of mechanical adjustments of the above listed units, since Electro-Mechanical Data Processing Equipment is basically standard within the industry.

Basically all Data Processing Equipment within the industry contain certain basic circuitry such as, Memory, Registers, Codes and Data Handling input and output equipment. Therefore, if a trainee is exposed to this circuitry and Electro-Mechanical equipment while in the Technical Schools, he would have good basic foundations to make him better qualified for employment in the Data Processing Industry.

As noted on curriculum some of us would object to "temperature" being classed as a "mechanical" function.

No - I don't believe it contains the basic courses that are necessary - physics - chemistry, etc.

The course description seems very complete, so complete that industry may be inclined to use the graduates electrically or mechanically, depending on their need and the student's choice of field. It is difficult to ascertain from the schedule presented the percentage of time spent on liberal arts type course material. However, considering the extent to which the tech. in our business are expected to verbally and compositionally express themselves, the course material may be a little light in this area. It would also be wise to consider in the design of the course material, the extent to which it will be transferable to accredited four year engineering colleges. Many technicians have a desire to obtain an engineering degree utilizing Company tuition refund programs and find their previous material not transferable.

Assume that lab work in various courses cover use of light microscopes, oscilloscopes, ultrasonic devices, pressure transducers, mechanical vibrators, stepping motors.

Appears excellent - especially computer work and instrumentation.

Somewhat heavier on the servo and telemetering area than we would need.

Additional coverage should be provided for Test Equipment and Meteorology. The curriculum should insure that the technician is able to cope with the electronic/mechanical interfaces and interrelationships in a given piece of equipment, system and/or machine. Provision should be made for acquainting these technicians with tape controlled machine tools.

The curriculum looks essentially acceptable with the following suggestions.

(a) We suggest the addition of some description of pneumatic amplifiers and control components.
(b) Increase the time of basic AC and DC circuit study.
(c) Spend less time on vacuum tubes and more on transistors.
(d) Some more emphasis on mechanical and pneumatic measurement.
(e) Remember to continually emphasize the basic concepts rather than the application of specific hardware.
(f) Emphasize the communication and economic aspects of the industrial world.

9. Do you have suggestions for electro-mechanical devices and/or systems that would be useful in the training program to illustrate applications of basic principles.

Perhaps any of the specially designed electro-mechanical items which reflect no consideration of maintenance matters, or which are "Knuckle-busters" from the operating standpoint, would serve to point up need for cohesive electro-mechanical training.

An Electro-mechanical circuit such as a machine protection circuit could be a useful tool in teaching someone how to "debug" a system. Many curricula teach how and why something works but not how to find out when something is wrong.

I believe the devices or systems you have indicated in the sample curriculum are adequate for our purposes.

Almost every controlling device being designed today uses electronic devices to operate mechanical controls. By 1970 automation will be very common and a whole rew servicing industry must be born to maintain these systems. Possibly this is phase two of your project.

Instrumentation such as process gas chromatographs, spectrophotometers, paramagnetic oxygen analyzers, and similar analytical instruments would certainly be helpful in the training of electromechanical technicians.

Several professional companies market training aids of general types to illustrate basic physical principles, more specific units will have to be made especially for the program.

Automated production lines in various industries.

Computers - Numerically controlled machine tools - Telemetry packages.

A system that would measure a pressure mechanical change to an electronic controller to transmit control signal to a control valve that has considerable lag between it and measured pressures.

Cameras with EE systems and battery line.

Tape recorders.

Sound motion picture projectors.

Without study, such suggestions would probably be too closely related to this company's particular problems, however, a list of such devices should be almost unlimited.

Relays-servos-actuators.

Basic instrumentation.

Hydraulic, pneumatic and vacuum systems.

Recording devices--Sanborn recorders, tape recorders, recording oscillographs.

Hydraulic drive systems--gear reduction devices--transfer of heat by gas and solids--mechanics of 3rd generation hardware.

Only to suggest keeping devices as basic or fundamental as possible to avoid over-specialization in pre-employment training.

a. Photo detectors and controllers operating registration systems.
b. "Norpac" systems handling feed of plastic laminated board to wrapping machines.
c. Solid state memory devices in systems such as used in rejecting empty boxes from filling machines.
d. Sam's Photofact Instrument Trainer for Flow, Level Instruments.

A present day aircraft flight control system exemplifies the combination of electrical, electronic, mechanical and hydraulic principles.

No, we do not make assemblies for sale and the work these technicians do is in the trade secret area.

FMC's "Checkweigher" would meet most of the requirements.

Gyroscopes, Accelerometer, and system combinations.
d.g., Stable Platform's

Recorders, Tape, X-Y and Strip Chart.

Repair and adj. of a high speed tape transport.

I firmly believe that there is a definite need for technically trained men in the above fields. My experience has led me to believe that there exists today, a situation which causes technical managers to assign graduate engineers to work on jobs which could easily be performed by technicians. The "situation" is: 1. The lack of trained technicians. 2. The lack of understanding on the part of technical managers that technicians can replace graduate engineers in special areas. We are "wasting" engineering talent.

The problem seems to be an interest bias towards either electrical/electronic (primary), or mechanical work, but seldom an equal interest in both. Your proposed curriculum will provide a needed mathematical discipline in the mechanical part of the field.

I find it impossible to make any kind of a meaningful guess as to our future requirements. Technology, automation, and product mix change rapidly. We have in the past recruited technicians trained in either electronics or mechanics and have then encouraged them through our tuition aid program to acquire additional training.

Operational Breadboarded Basic Hydraulics, Pneumatic, Aircraft Autopilot, AC & DC Servo Mechanisms, and Numerical Machine Control System.

I suggest that the final semester be devoted to specific hardware training of the industry having greatest need at the time. Need might also be measured by willingness to supply hardware and perhaps instructors.

As suggested previously, it would be highly advantageous for the Computer Industry if Technical Schools would incorporate training on actual computer equipment in their curriculum. Also, insure a heavy exposure to Electro-Mechanical adjustments on the input and output equipment.

No - a trained man of this kind would be of real value to us as well as other industrial firms providing we could work out certain jurisdictional assignment agreements with employee representatives. At the present time our scope of activities is large enough to justify use of specialists (electricians, electronics technicians, and machine repair technicians and craftsmen).

We feel more and more effort is being directed toward in-depth technical training at the expense of more fundamental courses, such as machine shop and related courses. Other extremely important courses for technicians are English, Report Writing, Oral Presentation, Chart & Graph Preparation, and Orderly Data Taking.

A useful training device might be an electric motor driven flow bench having various combinations of variable orifices, strain gauges and recorder gauges, heaters, thermocouples, meters, and hydraulic loading devices. Such a device by being spread out should allow sizeable number of students to work on separate parts of the system at any given time yet gaining an insight into the interdependent relationships of the parts to the whole. A rotational assignment system for the students through the various subsystems would substantially broaden their technical outlook.

We repair instruments and need particulary good basic training in Mechanics & Electronic Circuits.

(1) Governors and controls (2) Instrumentation.

Sound vibration equipment, Oscilloscopes, Telemetering devices, Keypunch understanding, Plotter.

Dr. Cox was selling a device which illustrated principles of thermoelectric. I believe it was used in some instruction areas.

Check weighers, Electronic sorters.

None specific but the smaller the better.

Tape controlled machine tools would be especially valuable since they provide the electronic/mechanical interrelationship and cover a wide spectrum of industrial applications.

Torque motors and associated driving amplifiers - Elec. typewriters- Hydraulic motor and speed control or a hydraulic positioning system.

Strength of materials should be included - The time phasing of subjects is extremely important.

We do not have any specific suggestions concerning training systems but we have seen many of them that are now available that would certainly be very effective in such a program.

It is difficult to simulate actual industrial situations in the laboratory. Therefore, it may be wise to include a practical experience tour in industry as part of the formal curriculum.

5-0158

FINAL REPORT
Project No. 46-27
Contract No. OE-6-85-057

ELECTROMECHANICAL TECHNOLOGY

A Post-High School
Technical Curriculum

Part II

November 1966

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

ELECTROMECHANICAL TECHNOLOGY
An Electromechanical Technology Curriculum

Project No. 46-27
Contract No. OE-6-85-057

Maurice W. Roney

November 1966

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The Oklahoma State University
School of Industrial Education

Stillwater, Oklahoma

Submitted by: The Research Foundation
Oklahoma State University

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FOREWORD

Technical education for industrial occupations has always been characterized by a base of mathematics and science with applications in a field of technology. In general, however, technical programs have been limited to one of the well-established fields of technology such as: electronics, chemistry, construction, or mechanics. Specialized course work in such programs concentrates on principles of technology as they apply to one of these fields.

The Electromechanical Technology Curriculum outlined herein has a mathematics and science base with applications in electricity, electronics, and mechanics. The emphasis in this instructional program is on the interrelationship of electronic and mechanical phenomena in systems and devices in which those phenomena are interdependent. The program is designed to prepare persons for certain emerging occupations in which a knowledge of these interrelationships is mandatory.

This curriculum is the result of a nationwide study of selected technical occupations in industry. It should be useful to technical school administrators in planning expanded institutional services in new and emerging occupational fields. The procedures used to develop the curriculum should be of interest to researchers, occupational analysts, and technical education specialists who are concerned with the development of interdisciplinary educational programs for occupations that require new combinations of skill and knowledge.

The materials for this report were prepared by Austin E. Fribance, Research Consultant for the Oklahoma State University Research Foundation.

Maurice W. Roney, Director
School of Industrial Education
Oklahoma State University
Stillwater, Oklahoma

ACKNOWLEDGEMENTS

The development of the Electromechanical Technology Curriculum was made possible by the contributions of a panel of industrial and educational consultants. Their work in selecting the industrial organizations to be included in the field research and in arranging personal interviews with responsible individuals in these organizations was invaluable. This panel also provided valuable assistance in reviewing draft materials for the curriculum and making suggestions for course content.

Though the members of the panel may not necessarily endorse all of the detailed recommendations included in this curriculum plan, they were unanimous in their support of the idea that special attention should be given to the education of technicians for the new occupations in the field of electromechanics.

PANEL OF CONSULTANTS FOR THE ELECTROMECHANICAL TECHNOLOGY STUDY

TED BOAZ, Director, Technical-Vocational Education, Del Mar Technical Institute, Corpus Christi, Texas.

ROGER W. BOLZ, Editor-in-Chief, AUTOMATION, Penton Building, Cleveland, Ohio.

GORDON L. BRATT, Technical and Vocational Training Branch, Department of Labour, Ottawa, Canada.

EDWARD BROGHAMER, Department of Mechanical Engineering, University of Illinois, Urbana, Illinois.

J. E. CASEY, Manager of Professional Programs, Leeds & Northrup Company, Bryn Mawr, Pennsylvania.

MALCOM EASTERDAY, Department Supervisor, Test Equipment, The Bendix Corporation, Kansas City, Missouri.

JOSEPH J. GERSHON, Vice President and Dean, DeVry Technical Institute, 4141 Belmont Avenue, Chicago, Illinois.

CLARENCE E. McNEIL, Corporate Education, International Business Machines Corporation, Armonk, New York.

CHARLES MERRITT, Manager, Datatape Engineering, Consolidated Electrodynamics Corporation, Pasadena, California.

JOHN C. NEW, Chief, Test and Evaluation Division, Goddard Space Flight Center, Greenbelt, Maryland.

JOSEPH A. PATTERSON, Texas Instruments, Inc., Semiconductor-Components Division, Dallas, Texas.

E. MARK SHELDON, Director, Control Data Institute, Minneapolis, Minnesota

BURTON K. SNYDER, Chief Engineer, Central Shops, Argonne National Laboratory, Argonne, Illinois.

ELECTROMECHANICAL TECHNOLOGY

Introduction

Occupational education is based upon the premise that the factors which contribute to success in an occupation are relatively well known and can be converted into certain educational experiences. Over the years, those elements which develop occupational proficiency have been identified and continually modified to meet changing occupational requirements. In recent years the trend has been toward post-high school education services. Specialized education beyond the high school is rapidly becoming a condition of employment for many industrial occupations. Post-high school technical education services have increased to meet this demand at the rate of approximately 20 per cent per year since 1958.

Along with the extension of occupational training into the thirteenth and fourteenth years of school, significant changes in instruction have evolved. The emphasis in occupational education has shifted from manipulative to cognitive skills. Technical education programs with a broad base of mathematics and science have been developed to prepare persons for employment in well-established fields of technology. Designed to fill the gap in our educational system, these field-oriented programs represent a second generation of occupational education. They supplement, rather than replace, high school programs of vocational education that are job-oriented.

There is increasing evidence that a third generation of occupational education is needed to keep pace with the fast-changing needs of technology. This third generation is a logical step beyond the single-technology orientation of most of today's technical education programs. Recent studies have shown that the lines of distinction between certain of these traditional fields of technology, i.e.; electrical, chemical, mechanical, are disappearing. Technical educators who take justifiable pride in the comprehensiveness of their broad-based program are faced with the distinct possibility that these programs may not be broad enough for the needs of their graduates in the future.

Dramatic evidence of the need for broader training was obtained in a nationwide study of electromechanical technician occupations conducted by the Oklahoma State University in 1966.* The 93 industrial organizations included in this study estimated their employment of persons with both electrical and mechanical training would be more than 50% greater by 1970 than their combined employment of single-specialty electronic and mechanical technicians. (See Appendix A).

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*Electromechanical Technology: A Field Study of Electromechanical Technician Occupations. Part I. Final Report Project No. 46-27, Contract No. OE-6-85-057. September 1966. U. S. Department of Health, Education, and Welfare, Office of Education, Bureau of Research.

This study also revealed that existing educational programs designed primarily to prepare specialists in either mechanical or electronic technology do not provide adequate preparation for the electromechanical technician occupations.

Experienced technical school administrators differentiate sharply between pre-employment educational programs for technicians and those designed to prepare specialists in skilled trades. The third generation of occupational education for industrial employment will have certain new parameters which must be identified with equal clarity.

It is reasonable to assume that much experimentation will be required to develop the instructional programs that produce new skill and knowledge combinations. It is unlikely that courses designed for single-technology curriculums will be useable in a dual technology program without considerable modification. Instead of lifting existing courses from single-technology curriculums, the curriculum designer will have to devise new courses that cut across traditional lines of demarcation.

This was the approach followed in the development of the Electromechanical Technology Curriculum outlined on the following pages. The design of the curriculum was influenced by two major considerations. The first was the cumulative experience of the project staff in technical education curriculum work. The project director, Maurice W. Roney, and the principal consultant, Austin E. Fribance each have several years of experience in developing curriculum guides for two-year programs. This experience included the development of Electronic Technology, Electronic Data Processing, Electrical Technology, Mechanical Technology, and Instrumentation Technology published by the U. S. Office of Education in a Technical Program Series. The second influence was the information obtained from the national field study of electromechanical technician occupations conducted in 1966. Details of the field study may be found in the report cited earlier.*

As a result of these two influences, the curriculum in electromechanical technology as presented here is a framework for innovation and experimentation based on experience and research. Every effort has been made in the explanations of the curriculum content to identify each of these influences.

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*See footnote on page 1.

General Principles for Design of a Technical Curriculum

The ultimate objectives of any pre-employment educational program for technicians have been defined.* A program should:

(1) Prepare the individual for employment in any one of several entry jobs in a field of technology.

(2) Provide a broad base of knowledge and technical skills that will enable the individual to advance to positions of increasing responsibility.

(3) Provide basic competencies that will enable the individual to continue study within his field of interest.

A technical curriculum, if it is to meet the first of these objectives, must be functional to the extent that graduates will have skills that enable them to become productive employees with a minimum of on-the-job training. In general, this is accomplished by making use of "hands-on" equipment in the instructional program wherever possible. The second objective requires that the program emphasize knowledge and thought processes rather than special techniques or procedures. The third objective of the curriculum makes it necessary to include a good foundation of mathematics, science, and communication skills. Advanced study in any technical field will normally require competence in these three disciplines.

In educational terms, these three curriculum objectives may only be realized by teaching technical principles. In teaching the technical principles it is important to use industrial equipment, wherever possible, to illustrate these principles. It should be understood, however, that the industrial equipment is only a means to an end. The principles to be learned will have many applications. Furthermore, all technical principles have mathematical and scientific bases which must be an integral part of the instructional program.

These three overriding requirements are usually supplemented with certain elements of general education. Some institutions will have certain legal requirements which make it mandatory to include courses in the social sciences and humanities if a two-year associate degree is granted as a completion credential.

In designing two-year technical curriculums certain basic guidelines are usually followed. These guidelines are found in other studies of technical education curriculums and may be summarized as follows:

1. The technical specialty should be introduced in the first term.

2. Mathematics and physical science courses should be correlated with technical courses in the first two terms wherever possible.

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*See U. S. Office of Education, Program Series in Technical Education, OE 80019 and OE 80021.

3. Provision should be made for independent problem-solving projects.

4. The total class and laboratory schedule for students should not exceed 28 hours per week and no term of the program should include more than 5 courses that require extensive outside study.

5. Outside study time should be calculated at 2 hours for each hour of scheduled class time in determining the total work requirement for students. The total work load should not exceed 56 hours per week.

Curriculum design in technical education requires special attention to the correlation of subject matter in concurrent courses during the first two terms of the program. Because of time limitations, (nominally two years), it is not feasible to schedule all mathematics, science and technical subject matter in sequential courses. Instead, it is necessary to introduce certain technical concepts at the beginning of the study program. Mathematics and science courses must be scheduled to parallel rather than precede this introduction to the technical specialty. Furthermore, technical course material must be analytical in nature, not merely descriptive. This requires that selected mathematics and science concepts be introduced at the outset and applied immediately in technical courses. This system of instruction contrasts sharply with the conventional practice in higher education in which mathematics and science skills are prerequisites for technical study.

The electromechanical curriculum described herein has additional requirements which increase the need for correlation of subject matter in concurrent courses. It is necessary in this program to coordinate the teaching of mathematics and physics with two specialized subjects: mechanical and electrical applications.

Special Needs of Electromechanical Technicians

The need for equal attention to mechanical and electrical principles throughout the training program was underscored by employers who participated in the field study of electromechanical technician occupations. The systems and devices with which these technicians work are often extremely complex electrical-electronics-mechanical combinations. Employers emphasized the need for technicians with sufficient knowledge of electrical and mechanical principles to make judgments where both are involved. It was pointed out that individuals trained as specialists in either of these two fields tend to avoid decision-making responsibilities where the two elements are interdependent. In extreme cases, electronics specialists literally refuse to become involved in decision-making where mechanical problems appear. Mechanical specialists are similarly reluctant to work with systems and devices that include electronic elements.

Throughout the field study employers emphasized the critical need for persons who feel equally at home in each of these elements.

Equal, if not more, importance was attached to the electromechanical technicians responsibility for the communication of facts and ideas. It was apparent from the discussions with employers that the dual-technology functions of a technician working in this capacity include a significant responsibility for interpreting technical information - as input for his own needs and as output for others. Here again, the unique nature of the communication skills needed in this occupation must be given consideration in the design of the curriculum. The need appears to be not so much for grammatical expertise as for technical accuracy. Obviously one without the other would be insufficient; both are required and both must be provided in the educational program.

Meeting these special requirements of the electromechanical technician occupation was the central objective of the Electromechanical Technology Curriculum.

Developing The Electromechanical Technology Curriculum Plan

The procedure followed in developing the Electromechanical Technology Curriculum plan was to apply known principles of technical curriculum design to the findings of an occupational study. The study revealed a need for technical personnel with new combinations of skills and knowledge. The resulting curriculum plan consists of new and untested combinations of course work that will, of necessity, require further development, modification, and evaluation in an actual teaching-learning situation. The plan calls for laboratories, instructors, and instructional procedures that differ in many respects from those in single-technology instruction programs. It should be emphasized, however, that although many of the concepts presented in the following description of the curriculum are unique, they represent a great deal of research and careful planning by experienced curriculum specialists. Throughout the period of twelve months spent in field research and curriculum design, continuous control was exercised by a Panel of Consultants which included representation from industry, government, and education. Details of the field study of electromechanical technician occupations are given in Part One of the project report.

An important part of the curriculum development process was the correlation of the occupational analysis with the instructional program planning throughout the project. This correlation was incorporated at several points in the project. The first point at which this occurred was a briefing session for the Panel of Consultants on the general form of technology curriculums. This step is extremely important. Industrial personnel are generally unfamiliar with the procedures and processes of specialized occupational education programs. Many kinds and levels of occupational education exist. Unless the limitations of two-year programs are well understood by advisory groups of this nature, they may not be realistic in making an identification of the occupations to be studied. It is the responsibility of the technical education specialist to delineate the proposed educational program before any attempt is made to study occupational needs. Failure to do this may result in much time being wasted by studying occupations for which the two-year technical program is not required. It is well to remember, also, that industrial job classifications and educational terminology are not yet sufficiently precise to provide the degree of reliability needed in educational planning.

For the electromechanical study, the advisory Panel was provided examples of two-year curriculums in electronic, mechanical, and similar fields. Several published guides were reviewed and the project director outlined for the Panel the scope and depth of existing two-year post-high school technical programs. Thus, it was clearly understood before the field study of electromechanical occupations got underway, just what level of technical competence could be expected as an output of the instructional program to be developed.

With this understanding the Panel was able to identify the kinds of job functions to be studied. Following the identification of job functions the Panel selected a representative group of industrial organizations to be included in the field study and, in many cases, recommended specific individuals in these organizations who could provide the necessary information. Here again, the advantages of having a well-defined area of instruction as a base of operation became apparent. In the majority of cases the individuals selected were directly responsible for work in which technical personnel were employed who required advanced training at this level.

The second phase of the field study, the in-plant interviews, also relied heavily on a correlation of educational planning and occupational analysis. Correlation was obtained in this phase by using an interviewer who was thoroughly familiar with the attainable level of instruction in technical education programs. It was possible by this means to reduce the interview time to a minimum -- an extremely important consideration since in all cases the time of high level administrative personnel was involved. The interviewer in this case was experienced, not only in the technical fields under study, but also in technical education. With this background it was necessary only for him to identify the significant differences between the functions and responsibilities of electromechanical technicians and those of electronic technicians and mechanical technicians. His extensive knowledge of the latter and their educational requirements enabled him to translate the former into educational specifications for the Electromechanical Technology Curriculum.

The personalization of the research at this critical stage can be all-important. First and foremost, it is essential that the interviewer reach those individuals in an organization who have major responsibilities for the technical work of the organization. Once he reaches these key people he must be able to discuss with them, in specific terms, the skill and knowledge elements under consideration. He must establish rapport with these individuals by demonstrating an understanding of their functions and responsibilities. Furthermore, the interviewer must make clear the educational significance of the information he is seeking. To do this he must earn the respect and confidence of those being interviewed. Finally, he must be able to translate occupational needs into educational programs.

The third step in the field study was a mailed request for information from employers to be used in making quantitative projections of the need for electromechanical technicians. This information was not requested, however, until after a tentative curriculum plan had been prepared to describe as accurately as possible the educational level of these technicians. Again, as in the preceding phases of the study, the educational and occupational requirements were closely related. Along with the request for information was a capsule description of a tentative curriculum plan. This plan was designed from information obtained in the field interviews and was reviewed by the advisory Panel. It was evident, from the responses from employers, that this procedure served to properly identify the kind of technical personnel being studied.

The Electromechanical Technology Curriculum

The field study of electromechanical technician occupations revealed certain general guidelines for pre-employment education in this field. These general requirements were summarized as follows:

1. The training should put emphasis on electrical and mechanical principles rather than on specific applications of these principles.
2. Communication skills are extremely important in the work of electromechanical technicians and should be given special attention in the training program.
3. A study of the interrelationship of electrical and mechanical elements of systems and devices should be central in the specialized technical courses of the instructional program. Whenever possible electrical and mechanical principles should be studied together, and not as separate entities.
4. Principles of electrical and mechanical physics are basic tools in the work of electromechanical technicians and all technical instruction should develop analytical skills for which these tools are fundamental. In addition, there is an increasing need for the technician to work with new applications of other physical sciences such as: optical equipment, thermal energy devices, hydraulic and pneumatic controls, and a wide variety of measuring instruments.

A major consideration in planning any new curriculum for tomorrow's technology is the length of time available for the total program. Because of the predominance of two-year institutions and two-year curriculums in existing technical education fields, it seemed desirable to plan a two-year program for electromechanical technicians. Admittedly many will feel that more time will be required. On the other hand, many employers prefer to employ the two-year graduate and have developed a job and salary structure for associate degree graduates. One solution to the problems encountered when the content of the two-year program is increased is to raise the ability level required for entrance to the program. When this is done it is often necessary to provide a pre-technology term for those whose background education is inadequate for the level of instruction in the first term of the technical curriculum.

The entrance level decided upon for the Electromechanical Technology program has been set at high school graduation with mathematics through trigonometry, a laboratory science, and mechanical drawing. While this is a relatively high entrance requirement in comparison to many technology curriculums, the alternative would be to require at least five semesters for the curriculum. In view of the trend toward pre-technology programs in technical schools the alternative plan was rejected. The principal reason for requiring this level of mathematics as an entrance requirement is to permit a comprehensive introduction to the physics in the first term as will be explained later. It should be noted, however, that although a substantial amount of mathematics is included in the curriculum, the basis for the technical study is primarily algebra and trigonometry. Selected topics of advanced mathematics are introduced after the first term.

The central core of electromechanical technology is a physical science, but the organization of instruction must be vastly different from that normally found in foundation courses in physics. It is mandatory in an Electromechanical Technology Curriculum that basic energy systems be introduced by concepts which have both electrical and mechanical applications. The imperativeness of this requirement can be understood by studying the parallel content of concurrent courses. A program for electromechanical technicians must coordinate the teaching of mathematics and physics with two specialized subjects: mechanical and electrical applications.

During the development of the curriculum it became apparent that to attain the objectives set for the program would require certain changes in the established instructional methods commonly found in college education. Students are likely to learn best when they see the importance of the subject matter - when there is repetition to reinforce the learning process, and when related subjects are so coordinated that they become mutually supporting. Such an approach requires not only new teaching methods, but a careful integration of subject matter in terms of time, to the end that each subject will obtain support from material being taught concurrently in other courses.

Perhaps of even greater importance to this type of approach is a realization that many of the principles which appear to be unique with a single technology, are also found in several others. In terms of fundamentals, there are only a few principles upon which all technical understanding is based. When the relative simplicity of these relationships and their universality are understood, it becomes possible to use common definitions, and terms. This not only reduces the amount of material to be mastered by the student, but reinforces previous experiences because the same principles, in slightly different form, are found in many applications. An example of unified concepts is shown in Appendix B.

The integrated teaching demanded by an Electromechanical Technology Curriculum has not only been discussed with industrial employers of technicians, but also with administrators, and teachers. Without exception, the opinion was expressed that such an approach seemed to offer the one means whereby the vast amount of technical material might be presented and taught effectively within the time limit of approximately two calendar years. The elements of an integrated teaching program were presented and discussed at three summer conferences held at Oklahoma State University and Pasadena City College during the summer of 1966.

In each of these conferences several practical problems which will impede the widespread use of such a teaching method have been identified. Some of these problems are:

1. The administrative staff must be aware of the problems involved in coordinating closely the work from several fields. Not only must time be made available for planning and sequencing of learning experiences, but teachers who are working in several areas will require extra time for preparation and lesson planning.

2. Text and laboratory materials are not now available, and they must be developed.

3. Teacher education programs must be conducted to familiarize teachers with the manner in which such coordinated teaching should be carried on.

4. Pilot programs should be conducted with students to determine what modifications should be made in materials, equipment or laboratory experiments.

A final check on the curriculum and the proposed system of instruction was provided by the Panel of Consultants at a meeting in Stillwater, Oklahoma, on December 13 and 14, 1966. At this meeting a final draft of this report was prepared which included the conclusions and recommendations. The Panel approved the report and all members present (Mr. Bratt and Mr. McNeil were absent) concurred in the findings of the study.

Curriculum Content and Organization

An outline of the Electromechanical Technology Curriculum is shown in Table I on the following page. The program outlined covers four semesters and a total of 70 semester credit hours of course work. If the optional summer term and a pretechnology term are required, the entire program can represent as much as 94 semester credit hours of work.

Table II is an analysis of the total time that the student is expected to devote to this program. Total time is computed on the basis of the generally accepted requirement of three hours of work per week for each credit earned. A sixteen week semester is presumed.

(R. 12-66)

TABLE I

ELECTRO-MECHANICAL TECHNOLOGY CURRICULUM

	ELECTRO-MECHANICAL COURSES*	PHYSICS COURSES	ELECTRICAL-ELECTRONIC COURSES	MECHANICAL COURSES	MATH & GENERAL EDUCATION COURSES	
	CLASS 1 LAB 3 CR. 2	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 4 CR. 4	CLASS 1 LAB 3 CR. 2	CLASS 5 CR. 5	CLASS 1 CR. 1
1st TERM	MECHANICAL COMPONENTS AND INTRODUCTION TO ELECTRO-MECHANICAL SYSTEMS	TIME AND SPACE UNITS BASIC ENERGY SYSTEMS MECHANICS (STATICS, DYNAMICS) MECHANICAL MEASUREMENTS -- TEMPERATURE, PRESSURE	ATOMIC AND MOLECULAR STRUCTURE (CONDUCTORS, SEMI-CONDUCTORS) BASIC ELECTRICAL UNITS D.C. CIRCUITS A.C. CIRCUITS	USE OF HAND TOOLS FITS AND FINISHES THREADS AND FASTENERS MACHINES AND MACHINE PROCESSES	REVIEW OF INTERMEDIATE ALGEBRA TRIGONOMETRY ADVANCED ALGEBRA	TECHNICAL REPORT WRITING
	CLASS 1 LAB 2 CR. 2	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 4 CR. 4	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 0 CR. 3	
2nd TERM	FLUID DEVICES HIGH VACUUM SYSTEMS HIGH ENERGY LIGHT SYSTEMS	SOLID STATE PHYSICS PRINCIPLES OF HEAT AND HEAT TRANSFER LIGHT AND OPTICS FLUID MECHANICS	A.C. CIRCUITS (CONTINUED) VACUUM TUBES SEMI-CONDUCTORS AND CIRCUITS POWER SUPPLIES AMPLIFIERS	MATERIALS TESTING ENGINEERING MATERIALS HEAT TREATMENT CORROSION	APPLICATIONS OF ANALYTIC GEOMETRY AND CALCULUS	
SUM					OPTIONAL SUBJECTS - ASSOCIATE DEGREE REQUIREMENTS, CHEMISTRY, ETC.	
	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 2 CR. 4	CLASS 3 LAB 4 CR. 4	CLASS 3 LAB 3 CR. 4	CLASS 2 LAB 0 CR. 2	
3rd TERM	SYNCHROS, RESOLVERS SERVO-MOTORS AND GENERATORS CHOPPERS, TACHOMETERS SERVO AMPLIFIERS FLUID SERVOS DIGITAL-ANALOG CONVERTORS TELEMETERING DEVICES RECORDERS, PLOTTERS	ELECTRICAL MOTORS AND GENERATORS SPEED CONTROL TRANSMISSIONS CLUTCHES AND COUPLINGS SERVO MECHANISMS INTRODUCTION TO CLOSED LOOP SYSTEMS	LOGIC CIRCUITS LOGIC SYSTEMS SYSTEMS ANALYSIS TIMING AND WAVE SHAPING CIRCUITS MEASURING INSTRUMENTS ELECTRICAL TRANSDUCERS	GEARS AND GEAR TRAINS PLANE MOTION DIFFERENTIAL MOTION MECHANICAL INTEGRATION TORQUE AMPLIFICATION AND FORCE AMPLIFIERS BEARINGS LUBRICATION	NUMBER SYSTEMS LOGIC SYSTEMS BOOLEAN ALGEBRA	
	CLASS 3 LAB 3 CR. 4	CLASS 3 LAB 3 CR. 4	CLASS 1 LAB 6 CR. 3		CLASS 3 CR. 3	CLASS 3 CR. 3
4th TERM	ELECTRO-MECHANICAL SYSTEMS DESIGN PRINTERS DIGITAL READOUT MISSILE CONTROL ELEVATOR CONTROL TAPE TRANSPORTS TELETYPEWRITERS DATA STORAGE & RETRIEVAL	ELECTRICAL, MECHANICAL, HYDRAULIC PROCESS CONTROLLERS VARIABLE POWER DEVICES COMPUTERS CLOSED LOOP SYSTEMS	DESIGN PROBLEM PROBLEM ANALYSIS DATA COLLECTION TECHNIQUES DATA EVALUATION TECHNIQUES PROBLEM DEFINITION PROBLEM SOLUTION(S) SOLUTION EVALUATION SOLUTION IMPLEMENTATION VERIFICATION		ECONOMICS	COMMUNICATIONS

* THE DEVICES AND SYSTEMS TO BE USED WILL BE SELECTED INDUSTRIAL APPLICATIONS. THE ITEMS SHOWN ARE TYPICAL.

ADMISSION REQUIREMENTS:
HIGH SCHOOL ALGEBRA, TRIGONOMETRY, MECHANICAL DRAWING, AND A LABORATORY SCIENCE.

A PRE-TECHNOLOGY TERM WILL BE NECESSARY FOR STUDENTS NOT MEETING THESE REQUIREMENTS.

TABLE II

Time Distribution of Subject Matter in the Electromechanical Technology Curriculum

Subject Matter Area	No. of Courses	Time Required in Hours			
		Class	Lab	Study	Total
Electromechanical	7	240	336	480	1056
Electrical-Electronic	3	144	192	288	624
Mechanical	3	96	176	192	464
Mathematics	3	160	0	320	480
Science	2	96	64	224	384
Communication Skills	2	64	0	128	192
Economics	1	48	0	96	144
TOTALS	21	848	768	1728	3344

In terms of credit, technical courses (45 hours) make up 64 percent of the total curriculum, communications and economics (7 hours), 10 percent.

The curriculum is designed to provide a close correlation of subject matter in concurrent courses during the first two terms. Experience in other curriculums, especially those in electronics technology, has shown this to be a critical point in the study program for many students. The subjects areas that require correlations are mathematics, physics and electricity. Mathematics forms are introduced in the mathematics courses and applied immediately in physics and electricity courses. This has the effect of encouraging the student to develop speed and accuracy in the use of mathematics. At the same time it makes possible the analytical approach in electricity and physics-mechanics that is essential in developing a sound base for the technical courses which follow.

Another requirement in technical curriculum design is an immediate introduction to the technical specialty. This is accomplished by an introductory electromechanical course in the first term - in this case a descriptive course in components and systems. It is well known that technical students tend to be pragmatic, to the extent that they are likely to lose interest in courses such as mathematics and physics unless they are shown the need for skills in these disciplines. An introduction to electromechanical components and systems serves to whet the student's interest while at the same time it provides them an opportunity to become familiar with the technical terms, physical characteristics, and functional aspects of the complex equipment which they will study in greater detail later in the program.

Perhaps the most significant advantage obtained by the correlation of subject matter in the first term of the study program is the balance of electrical and mechanical subject matter. It is imperative that both of these disciplines be given equal emphasis at the outset if students are to develop an electromechanical concept.

A somewhat unique plan for developing communication skills is advanced in the Electromechanical Technology Curriculum. Instead of requiring the customary English course in the first term this plan calls for a basic introduction to report writing. The reasoning behind this plan is that students are not likely to develop skills in technical communications until they acquire at least a minimum vocabulary of technical terms. With an understanding of the requirements for technical reporting the student is expected to develop an appreciation for accuracy of expression by actually preparing reports. As he continues in the program he will be required to meet progressively higher standards in both oral and written reports. A three-credit course in communications skills is scheduled in the last term of the curriculum. At this stage of the program the student should have identified his personal weaknesses and should have a much better appreciation for the need to improve his ability to communicate.

Courses and Course Content

At this stage in the development of the curriculum it is possible only to indicate the topics to be covered in the two-year program. The following topic outline represents the subject matter suggested for each of the four terms. The amount of time indicated for class and laboratory are estimates, based on experience with two-year curriculums in electrical and mechanical technology. The amount of laboratory time to be devoted to each topic will be a function of the quality and quantity of laboratory equipment available. Thorough planning, experimentation, and practice will be required to make this determination. Much additional research and development is needed in this area.

CURRICULUM OUTLINE

FIRST TERM COURSES	Course Content, Class and Laboratory Time in Hours
Electrical-Electronic	Class 3 Lab 4
Electrical Materials	Conductors, semiconductors, insulators Atomic and molecular structure
Basic Electrical Units	Fundamental units of measurement, meters

DC Circuits	Simple series, parallel circuits; power equivalent circuits, Thevenin's and Norton's theorems
AC Circuits	Sinusoidal generation, average, rms, maximum values; resistance, reactance, impedance, phasor representation, single phase systems

Mechanical (Lab or Shop)	Class 1	Lab 3

Use of Hand Tools	Provide basic manual skills together with the use of basic tools most frequently used
Fits and Finishes	Production standards and methods of measurement
Threads and Fasteners	Classifications and standards
Machines and Machine Processes	Acquaintance with the machine tools normally employed in metal fabricating, shaping and joining

Electromechanical	Class 1	Lab 3

Mechanical Materials	Introduction to mechanical systems and components: gears, pulleys, levers, clutches, etc.

Physics	Class 3	Lab 2

Time and Space	Units of time and distance-speed, velocity, acceleration, linear and rotary motion
Basic Energy Systems	Kinetic, potential unified concepts
Mechanics	Statics, Dynamics
Mechanical Measurements	Temperature, pressure, level, flow

Mathematics	Class 5	Lab 0

Review of Intermediate Algebra	
Algebra	Through Quadratics and simultaneous equations

Trigonometry	Right triangles, functions of any angle, components, coordinate to polar conversions, identities
Advanced Algebra	
Technical Report Writing	Class 1 Lab 0
	Applicable to all phases of program. Emphasizes form of reports, means of presenting data, data collection, determination of results

SECOND TERM COURSES	Course Content, Class and Laboratory Time in Hours
Electrical-Electronics	Class 3 Lab 4
AC Circuits (Cont.)	Polyphase systems; delta-wye conversions, Power factor correction
Vacuum tubes	Fundamentals of thermionic devices
Semi-conductors and Circuits	First course in solid state devices, transistors, diodes
Power Supplies	Conventional and special power supplies
Amplifiers	Voltage and power amplifiers
Mechanical	Class 3 Lab 2
Materials Testing	Tensile, compressive, fatigue, hardness, and nondestructive tests.
Engineering Materials	Characteristics of common materials
Heat Treatment	Materials, temperatures, and atmospheres
Corrosion	Corrosion effects and protection
Electromechanical	Class 1 Lab 2
Fluid Devices	Principles of operation of hydraulic and pneumatic devices and systems; servo-systems
High Vacuum Systems	Means of obtaining high vacuum at various temperatures
High Energy Light Systems	Lasers, masers, etc; optics and optical systems

Physics	Class 3 Lab 2
Solid State Physics	Simple concepts, particularly with respect to resistors, conductors, and semiconductors
Principles of Heat and Heat Transfer	Thermal resistance, means of measurement, capacitance, time constant responses
Light and Optics	Basic principles of light, illumination, and lens systems
Fluid Mechanics	Pressure, resistance, flow and thermal characteristics

Mathematics	Class 3 Lab 0
Applications of Analytical Geometry and Calculus	Meaning of slopes, rates, maxima & minima, integration, differentiation

SUMMER TERM COURSES

Social Science Humanities	If required for associate degree programs
Industrial Chemistry	

THIRD TERM COURSES	Course Content, Class and Laboratory Time in Hours
Electrical-Electronic	Class 3 Lab 4
Logic Circuits	Construction and operation of typical circuits and their responses.
Logic Systems	Construction and response of magnetic, optical, electrical systems
System Analysis	Predicting the response of a system based upon the frequency response characteristics of its components
Timing and Wave-shaping circuits	Applications, limitations, construction and theory
Measuring Instruments	Visual, digital, electronic, analogue
Electrical Transducers	Transducers of pressure, temperature, flow, position, pH, viscosity, composition

Mechanical

Class 3 Lab 3

Gears and Gear Trains	Fundamental mechanical components which will find application as units or as parts of systems. Determining of sizes, life, operating conditions.
Plane Motion	
Differential Motion	
Mechanical Integration	
Torque Amplification and Force Amplifiers	
Bearings, Lubrication	

Electromechanical

Class 3 Lab 2

Synchros, resolvers	Electromechanical devices with which the student should be familiar and which are fundamental components of many electromechanical systems.
Servo Motors and Generators	
Choppers, Tachometers	
Servo Amplifiers	
Fluid Servos	
Digital-Analog Convertors	
Telemetering Devices	
Recorders, Plotters	
Electric Motors and Generators	AC and DC motors; Theory and principles of operation and application
Speed Control	
Transmissions	Hydraulic, mechanical
Clutches and Couplings	Mechanical, eddy-current, hydraulic
Servo Mechanisms	Basic components and operation
Introduction to Closed Loop Operation	

Mathematics

Class 2 Lab 0

Number Systems	Characteristics of Number Systems

Logic Systems	Application in computers
Boolean Algebra	Uses in simplifying circuits and systems
FOURTH TERM COURSES	Course Content, Class and Laboratory Time in Hours
Electromechanical	Class 3 Lab 3
Industrial Controllers	Process and machine tool controllers of the electrical, hydraulic, and pneumatic types
Variable Power Devices	Welders, speed control, furnaces, machine tools
Computers	Digital and analogue
Closed Loop Operation	Typical feedback systems and requirements for stability
Electromechanical	Class 3 Lab 3
Printers	Basic electromechanical systems with which the student should be familiar. The principles will be employed in the Design Problem
Digital Readouts	
Missile Control	
Elevator Control	
Tape Transports	
Teletype Setters and Teletype	
Data Storage and Retrieval	
Electromechanical	Class 1 Lab 6
Design Problem	Combines a study of analysis and problem solving, with application to a specific problem.
Problem Analysis	
Data Collection Techniques	
Data Evaluation Techniques	

Problem Definition

Problem Solution(s)

Solution Evaluation

Solution Implementation

Verification

General Education

Economics	Class 3	Lab 3
Economic Theory		
Cost-Benefit Analysis		
Economics of Production		
Communications Skills	Class 1	Lab 3
Expository Writing		
Public Speaking		
Conference Procedures		
Technical Writing		

Special Requirements of the Curriculum

The instructional program requires both a carefully structured arrangement of subject matter and almost a day by day coordination of effort by all teachers in the program. Conventional courses in mathematics, physics, electronics, etc., cannot provide the required "simultaneity" of treatment which is a key part of the program. Moreover, everything possible must be done to destroy the lines which separate electronics from mechanical elements; and electrical technology from that of instrumentation, for example. To the greatest degree practicable, all barriers must be eliminated so that the student acquires equal facility in all areas - he must not be an electronics technologist with experience in related mechanical subjects, or vice versa. Rather, he must feel equally at home in both the electrical-electronic and the mechanical areas. The degree to which all dividing lines can be eliminated will, in large measure, determine the success of the program.

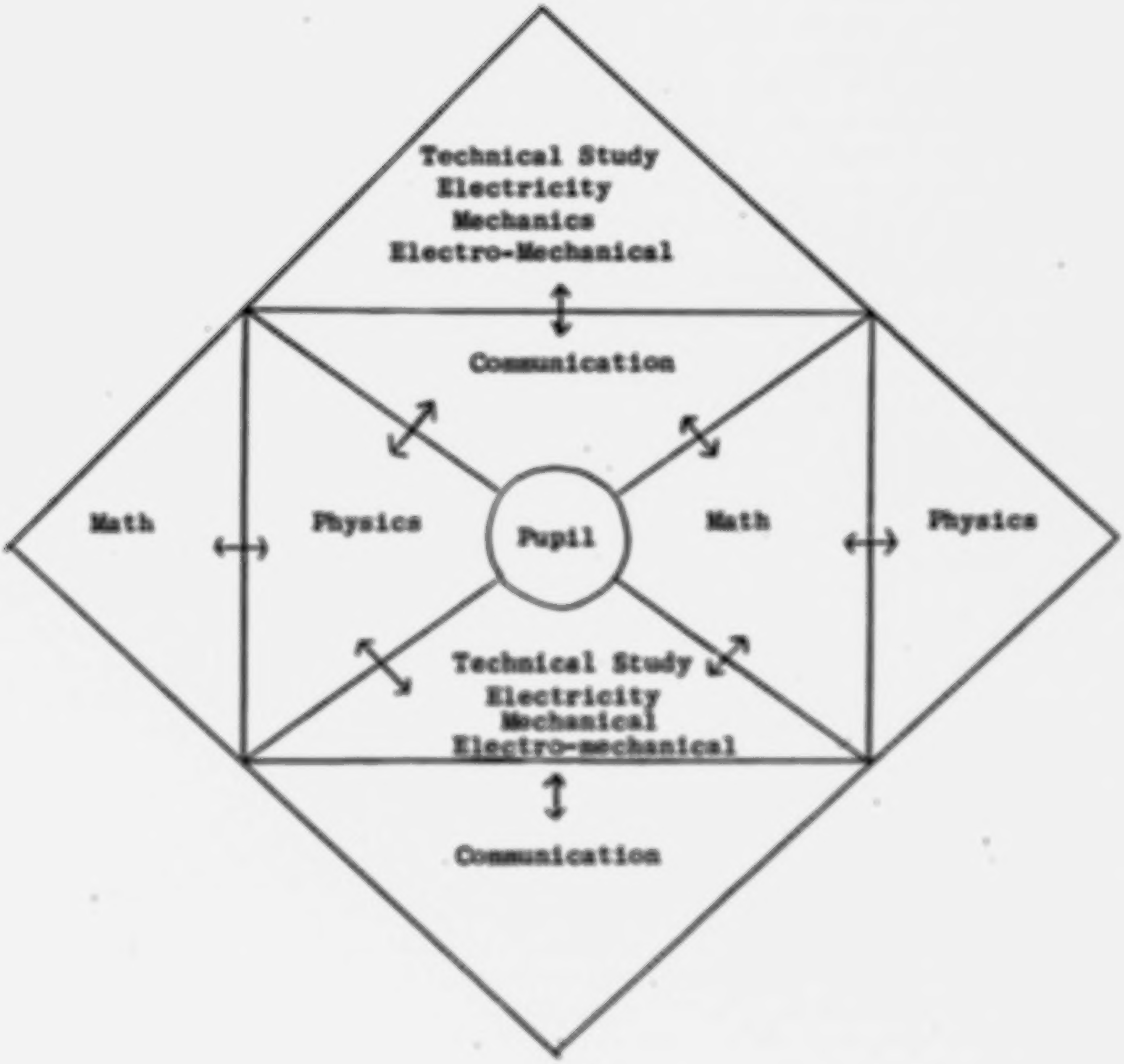
What has been proposed for a curriculum constitutes only the bare bones. It must be clothed with suitable text materials, laboratory equipment and experiments, but most important of all is the faculty, who must convert the inanimate elements into an organized plan of dynamic educational experiences. Because all three elements will have to be developed, it would be well to consider some of their characteristics.

The Faculty

The most important single factor in the creation of an effective educational program is an enthusiastic and competent faculty. Inanimate teaching aids and facilities are of little use by themselves, and in all planning and budgeting the primacy of the instructional staff should be recognized. A successful interdisciplinary program requires teachers who are reasonably competent in more than one discipline in order that each course may be properly correlated with other instructional activities.

In a program of interrelated teaching there is no one subject which is more important than another. The central figure is the student or pupil, and all educational activities are aimed at his development. Teachers cannot limit their concern to a single discipline, but rather must recognize that their particular specialty is subordinate to the general development of the individual. Moreover, any given subject must be taught in its proper relationship to the other programs which comprise the curriculum. In graphical form this relationship is shown in Figure A where it will be evident that each of the four subjects shown is related to all other parts of the student's program. The same interdependence of subjects should hold regardless of the number of subjects being considered. The important thing is the philosophy that teaching is not limited to a single area of interest, but supports, strengthens, and reinforces every other part of the program.

FIGURE A


Technical Study
Electricity
Mechanics
Electro-Mechanical
Communication
Math
Physics
Pupil
Math
Physics
Technical Study
Electricity
Mechanical
Electro-mechanical
Communication

For example, the mathematics teacher who has had a good course in physics (as most will have had) might well teach some of the physics laboratory classes; the physics teacher should be competent to assist in the electrical or electronics laboratory.

The teacher responsible for communications skills may require the greatest amount of versatility. He most certainly cannot limit his teaching function to the mechanics of writing. Instead, he must be able to search out and capitalize on the specific needs of students at each phase of the program. He must recognize that without the ability to communicate, in very specific ways the technician will be poorly prepared to perform his function in industry. The following comment from one of the industrial representatives included in the occupational study is typical:

> "In looking over curricula of various technician programs, the weakness appears to be in the communicative skills area. Here are the weaknesses we find in technical undergraduates. If the technician is to play a more significant role, he must be able to communicate. We are interested in technicians with electromechanical backgrounds who can communicate."

An instructor in this program cannot be a prima donna. He must function as a member of a team. His relations with the rest of the staff must be such that he feels that they can reinforce his instruction by example, application, and repetition. He no longer can operate alone, but must always be in concert with the other staff members.

It will no longer be sufficient for him to be only a subject matter specialist. He will have to extend his knowledge and experiences so that in his own classes he too may reinforce the work in the mathematics classes, the physics classes, the electronics classes, and communications in all its forms.

He will have to spend much extra time planning lessons because they will have to be closely integrated with every other part of the curriculum. Unless he is willing to give adequate time to this phase of teaching, the program quite likely will fail. Only to the degree that all teachers cooperate and subordinate their individual preferences can the curriculum be successful.

A most important phase of the teacher's qualification is his industrial experience, which should be as extensive and as up-to-date as possible. One of the major problems of instruction, as evidenced by comments obtained during the field study, is that educational practices often lag behind industrial practices. One technical institute program which was favorably reported on during the field survey is said to owe its high reputation to an efficient staff of instructors who keep current in their field.

Instructional Materials

Textbooks with the integration of subject matter required for Electromechanical Technology are not currently available. Nevertheless, prepared instructional material together with laboratory manuals and prepared experiments, can do much to accelerate the educational process. Instructional materials will have to be developed. The teacher of mathematics might well use principles of physics to illustrate his mathematical relationships. Inasmuch as it is rare that a student will encounter "x" or "y", he might well graph the variations of resistance with temperature, or the change of pressure of a confined gas as its temperature changes. In this manner the student is exposed to the principle in more than one situation; in this way the mathematics teacher can reinforce the work of the physics teacher. In a similar manner the physics teacher works in close coordination with the teacher of electronics. The teacher of instrumentation will need the assistance of the electronics, the physics and the mathematics teachers if he is to achieve the greatest success in his teaching. Simultaneously, the student has example, application, and repetition to aid him in his mastery of basic principles.

Instructional materials incorporating these concepts must be available before this curriculum can become a dynamic program of instruction.

Laboratories

Many of the laboratory facilities required for the electromechanical technology program will be available in schools where electronic technology and mechanical technology programs are in operation. Under normal conditions, it is quite probable that existing electrical, electronic, mechanical and instrumentation laboratories will be available. Two special laboratories will be required for the electromechanical courses. These special labs, to be used a total of 20 hours per week for scheduled laboratory classes, would be available for special project work at other times during school hours. These labs should be equipped with modern electromechanical systems and devices selected to represent a range of principles from the simple to the complex. Provision should be made for project work and the labs should be equipped with high quality testing and measuring devices. It is recommended that the services of a laboratory technician be made available to maintain equipment and assist with ongoing project work.

The electromechanical laboratories provide a true integration of the electrical-electronic and mechanical technologies where the systems approach appears to offer several distinct advantages. Conventional laboratory equipment is not suited to the objectives of the program. Consequently, it will be necessary to develop the electromechanical laboratories and their associated experiments.

Those laboratories should include industrial equipment which will illustrate the operation of systems and devices which can be used to teach specific principles of physics, electricity, electronics, instrumentation, and mechanical principles.

To the greatest degree practicable, the equipment used for laboratory exercises should also be the basis for some of the related work in physics, electronics, and mathematics. The principles studied in the technologies should involve current design and manufacture.

A study of systems and a variety of devices can do much to break down any feeling of interest in one particular technology - one of the points stressed by industrial representatives in the field interviews during the occupational study.

Some of the principal areas of study to be presented in the electromechanical laboratory are:

1. Speed, displacement, acceleration; linear and rotary motion
2. Forces, components, forces at a point, moments, torque
3. Magnetic fields (motor, clutches, eddy currents, generation, LVDT)
4. Cams, sequencing and indexing devices
5. Mechanical clutches, bearings, lubrication, gears, and levers
6. Analog and digital computation
   Electrical, fluid, pneumatic, hydraulic
7. Electro optical devices - photo readers, printers
8. Principles of automatic process control
9. Relationships of mass, inductance, capacitance, resistence,
   Friction time-constant relationships and components
10. Electrical, hydraulic, pneumatic systems and their response; separately and together
11. Logic systems - electrical, hydraulic, pneumatic

The following appear to be the general areas which should be investigated for apparatus and components which will be most suitable:

1. Potentiometric Recorders--single and multiple read-out
   Single speed motor
   Potentiometric balancing
   Clutches
   Solenoids
   Amplifier-detector

2. Numerically Controlled Machines

3. Teletypewriter, electric typewriter (remote control), tape handler, weighing systems

4. Automatic test and manufacturing equipment

5. Automatic wiring machines and component inserter

6. Small step-by-step telephone exchange
   - Line-finders
   - Rotary-switches
   - Cross-bar

7. Transducers - force, LVDT, distance, emf, resistance, optical, temperature, pH, humidity
   - Semi-conductor strain gages - gage elements
   - Pressure-to-pressure

8. Temperature - Thermocouples
   - Potentiometer with automatic or manual current balance
   - Resistance - linear - wire
     - thermistor (nonlinear)
   - Optical - color matching.
   - Radiation - thermocouple, thermistor
   - Temperature-to-current

9. Distance - LVDT; linear multi-turn potentiometer with gear train differential amplifiers

10. Humidity - variable resistance devices; variable dimensions

11. pH - Electrodes + high gain amplifier + potentiometer

12. Strain gages - wire; semi-conductor
    - pH to current and emf
    - Temperature to current and emf
    - Resistence to current and emf
    - Emf to current and emf

13. Variable speed drives
    - Mechanical - manual and air operated
    - Hydraulic - clutches - hydraulic pumps and motors
    - Electrical - eddy current clutches
      - variable voltage and variable frequency
      - saturable reactor, silcon controlled rectifier

14. Fluid flow systems - pumps, controls, meters, pumps, motors

    Metering Fluids:
    - Differential pressure
    - Turbine - frequency
    - Reaction - torque
    - Nonturbulent flow
    - Rotameter

15. Hydraulic pilot valve operation of x-y positioner (1' x 1')
    - Electrical positioning
    - Electrical detectors - counters
    - Electrical pneumatic position detector
    - Hydraulic and pneumatic logic

16. Power control-electrical contactor - on-off
    - Proportional + Rate
    - Proportional + Reset

    - Control small furnace
        - Record, measure, control; add rate and reset responses
        - Hydraulic - pilot valves, hydraulic pumps and outputs

    - Pneumatic
        - On-off
        - Proportional
        - Reset
        - Rate

17. Analog Computation
    - Pneumatic pressure transmitters and definite pressure transmitters
    - $(A + B)$; $(A - B)$
    - $(A + B + C)$; $(A + B - C)$
    - A^2, $A^2 + B^2$
    - Operational amplifier
    - Square route extracters
    - Electrical additional and difference; potentiometric current balance. Use of operational amplifiers for adding, subtracting, and multiplying

18. Digital computers and associated equipment
    - card readers

19. Optical systems and associate apparatus
    - lens, photographic

CONCLUSIONS

1. The increased complexity and the closely interrelated character of electromechanical systems makes it desirable that technicians be equally capable and proficient in each of the technical areas. Their educational program must integrate the two technologies so that they become mutually supporting elements having a common objective.

2. It appears feasible to teach electromechanical principles within the time limits of a two-year program by using a correlated teaching system in which each subject reinforces other subjects in the curriculum. Such an instructional technique will require extensive development. The amount of material which should be included in an electromechanical curriculum cannot be presented within the desired time interval of two years if conventional methods are used.

3. With the educational background, provided by the proposed program, the graduate technician should be prepared to learn the highly specialized techniques peculiar to a particular job, and is prepared for continued study and growth in the electromechanical field.

4. It is impossible to express this curriculum in conventional terms, using familiar names for courses, when there is to be integration of subject material.

5. Suitable text materials and laboratory experiments for interrelated teaching are not presently available. The development of these materials will be an important element in the development of the instructional program.

6. In order to obtain the desired merging of the electrical-electronic and mechanical technologies it will be necessary to develop new laboratory approaches which make use of modern electromechanical systems and devices. These will be used not only in the electromechanical phases of the program, but also in support of the physics, the electronic, and the mechanical courses.

7. Administrative officials in any institution where this program is to be offered will need to make provisions for a high degree of staff planning and coordination in order to maintain the proper relationship of program material.

8. Each faculty member in an interrelated program will have to be reasonably competent, in more than one discipline, and must display a willingness to cross over into related disciplines for purposes of integration.

9. The success of the proposed electromechanical program will depend to a large measure on a continuous developmental program involving teacher training, preparation of instructional materials, and the development of laboratory facilities.

10. An active advisory committee is most important in developing and evaluating a curriculum in this emerging field of employment.

11. While the remarks about the study have been directly concerned with the electromechanical technology, they should not be viewed in such a restricted sense. The principles seem to be applicable to some extent to all technologies - in fact, it would appear that the principles can be applied at all levels of education.

RECOMMENDATIONS

The conclusions reached in this study of the emerging occupations in electromechanical technology support the need for a new kind of instructional program. The proposed curriculum reflects the unique requirements of these occupations and is presented as a framework for experimentation and innovation. With these two basic premises as guidelines the following recommendations are made:

RECOMMENDATION NO. 1

New programs of Electromechanical Technology should be planned and implemented as soon as possible.

Existing and projected needs for electromechanical technicians establish this as one of the most urgently needed educational programs. Although much developmental work is needed, schools should be encouraged to begin planning new programs in this field as soon as possible.

RECOMMENDATION NO. 2

The major effort in developing new programs for electromechanical technicians should be devoted to two-year associate degree level curriculums.

Employment policies of organizations appear to favor the two-year graduate for the electromechanical technician occupations. A well-integrated, two-year, post-high school program should be sufficient preparation to enter the occupational field. It should be recognized, however, that the nature of the interdisciplinary study (physics - electronics - mechanics in the first term) imposes specific entrance requirements. A pretechnology program will be required for those students who are not prepared to apply mathematics (basically algebra and trigonometry) in the first term courses.

RECOMMENDATION NO. 3

Schools with existing programs of Electronic and Mechanical Technology should not expect to develop Electromechanical Technology programs by assembling existing courses and utilizing existing instructional staff without further training.

Major revisions in course content, course sequences, subject matter correlation, and instructional facilities will be required. Above all, the philosophy and the objectives that form the base for an interdisciplinary program are sufficiently different from those of a single discipline program to require extensive reorientation and retraining of the instructional personnel who will be involved.

RECOMMENDATION NO. 4

An extensive research project should be planned and carried out to further develop and document the instructional plan proposed for the curriculum in Electromechanical Technology.

This developmental work should incorporate the instructional procedures and techniques outlined in this report. The project should include all of the following elements:

1. Conferences of school administrators interested in developing new technical education services
2. Training institutes for teachers
3. A pilot program with full-time students
4. Development of instructional materials
5. Development of special laboratories
6. Development of a pretechnology program for students who do not meet the established entrance requirements
7. Complete documentation and continuous dissemination of the instructional materials and staff training procedures that are developed.

This project should be expected to cover a period of from thirty-six to forty months. It should be funded through the cooperative efforts of industry, government, and other agencies with an interest in promoting technical education services.

RECOMMENDATION NO. 5

Research studies should be made in other emerging occupational fields which require new combinations of technical skills.

The highly successful technique employed in this study should be useful in any study of occupational and training needs where technical personnel appear to need cross-disciplinary or multi-disciplinary skills and knowledge. Examples may be found in the fields of health, agriculture, and the biological sciences.

APPENDIX A

EMPLOYMENT AND PROJECTED NEEDS FOR TECHNICIANS IN 93 INDUSTRIAL ORGANIZATIONS**

Organizations by Principal Product or Activity	Number of Responses	No. of Technicians* with Specialized Training				Projected Needs for Technicians (New Hires)					
						Electronics		Mechanical		Electromech.	
		Total	Electrical	Mechanical	Other	1967	1970	1967	1970	1967	1970
Manufacturing	60	34,303	30,351	2,552	1,400	2,944	10,301	840	2,530	4,666	18,478
Research & Devel.	14	973	405	280	288	87	131	64	113	77	177
Design	3	111	76	33	2	4	4	5	5	13	19
Calibration & Test	12	1,501	1,176	214	111	62	102	26	56	1,060	1,652
Other	4	81	15	41	25	1	3	7	15	4	3
TOTAL	93	36,969	32,023	3,120	1,826	3,098	10,541	942	2,719	5,820	20,329

*Includes only those who work with both Electrical (Electronic) and Mechanical Devices and/or Systems

**This material from Electromechanical Technology: A Field Study of Electromechanical Technician Occupations. Part I. Final Report Project No. 46-27, Contract No. OE-6-85-057. September 1966. U. S. Department of Health, Education, and Welfare, Office of Education, Bureau of Research.

APPENDIX B

Example of Unified Concepts

Since there is a common definition for electrical resistance, we may start with:

$$R_{(elect)} = \text{volts}/_{\text{ampere}}$$

Then, by multiplying numerator and denominator by time, we obtain:

$$R_{(elect)} = \frac{\text{(Volts) (seconds)}}{\text{(ampere) (seconds)}} \qquad \frac{\text{(Volt) (seconds)}}{\text{Coulombs}}$$

We might then generalize to obtain a universal definition of resistance. Energy cannot be transferred without some difference in level existing or being created. In place of the electrical quantity expressed in coulombs, we might merely convert the denominator into "Quantity", with the result that:

$$\text{Resistance} = \frac{(\text{Energy level}_1 - \text{Energy level}_2)\ (\text{Time})}{\text{Quantity}}$$

This single definition can then be used for thermal, hydraulic, electrical, and pneumatic phenomena. Regardless of the type of energy involved (excluding chemical and potential energies), there cannot be a transfer of energy from one location to another without having a difference in levels. It will always take time to effect this transfer; and some definite quantity of charge, heat, or amount must be involved in the transfer. In trying to get the student to work in several fields, he should be greatly aided if he can see that the various types of systems are all following the same basic laws.

In the situation dealing with heat, thermal resistance is measured by the temperature differential and the time required to transfer some amount of heat. Perhaps it is more evident in the thermal case than in the electrical example that there is always a difference in the temperatures which governs the rate at which heat is transferred from one point to another. Suppose that when one temperature is 400 degrees and the other is 200 degrees, that 200 BTUs are transferred in an interval of 10 minutes. For these conditions:

$$R_{\text{thermal}} = \frac{(T_1 - T_2)\ (\text{Time})}{\text{Quantity of Heat Transferred}}$$

$$= \frac{\text{(400 degrees - 200 degrees) (10 minutes)}}{\text{200 BTUs}}$$

$$= \frac{\text{(200 degrees differential) (10 minutes)}}{\text{200 BTUs}}.$$

$$= \frac{\text{10 degree - minutes}}{\text{1 BTU}},$$ or with seconds as the measure of time, this becomes

$$= \frac{\text{(200 degrees) (600 seconds)}}{\text{200 BTUs}}$$

$$= \frac{\text{600 degree - seconds}}{\text{1 BTU}}$$

A fluid cannot be made to flow through a pipe or conduit unless there is some differential pressure available to overcome the resistance or retarding effect of the conducting tube, pipe, or vessel. Thus in the fluid case, with either liquids or gases we know that a differential pressure is required to establish some given rate of flow. For example, if the inlet pressure to a pipe is 50 psi, and the pressure 40 feet downstream is 45 psi when a fluid is flowing at the rate of 20 pounds per minute, then the resistance of that section of pipe could be easily ascertained from our definition of resistance.

$$R = \frac{\text{Differential Pressure}}{\text{Rate}} = \frac{\text{(differential pressure)}}{\text{Quantity / time}}$$ By simple algebraic manipulation this becomes

$$= \frac{\text{(Differential Pressure)(Time)}}{\text{Quantity}}$$

$$= \frac{\text{(50 psi - 45 psi)(1 minute)}}{\text{20 pounds}}$$

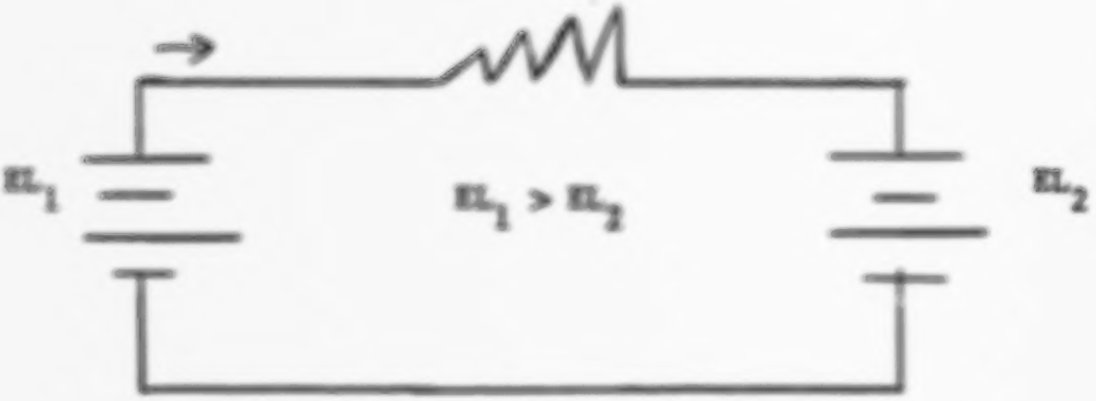
$$= \frac{\text{(5 psi)(1 minute)}}{\text{20 pounds}} = \frac{\text{(5 psi)(60 seconds)}}{\text{20 pounds}}$$

$$= \frac{\text{0.25 psi - seconds}}{\text{1 pound}}$$

When dealing with different types of flow situations, whether we are concerned with electrical, thermal, hydraulic, or gaseous conditions, the same relationships hold. Consequently, they may all be expressed the same way; and we should anticipate similar types of performance.

If we employ the basic concept that it is a "difference in energy level", whether it be electrical pressure in volts, thermal pressure in terms of degrees, or pressures in pounds per square inch, then a single type of elementary circuit can be used for all of these fundamental relationships, as shown in Figure B. In a special case, EL_2 might be zero.

FIGURE B



EL_1 and EL_2 may be expressed in degrees, psi, volts, etc.

But such a simple circuit goes far beyond "resistance" relationships. Mastering its concepts paves the way to understanding direct current motor controls which are based upon the difference between the impressed and the self-generated internal counter electromotive force. Electrical transformer action also depends upon this "difference" of potentials. In the case of the saturable reactor, one of the potentials is caused to go to zero at some desired moment. Thus one simple relationship can be used over and over again to explain hydraulic, electrical and thermal relationships and phenomena.

In a similar manner we find that there is a universal definition of "capacitance" which finds its applications in thermal 1 and hydraulic as well as electrical situations.

Systems having resistance and capacitance also possess other common qualities or properties. None of them can respond without some delay - all of them will take a certain amount of time, governed by the product of their resistance and capacitance, if one uses the classical approach using the differential equation. (However, it is possible to arrive at the same result by using logic and the meanings of the quantities involved.) The responses of all these systems -- regardless of their type, are the same. Consequently, if one knows what any given system will do under certain sets of conditions, then he also knows what all of the other systems will do with like parameters.

Thus, from some very simple common definitions we are able to study and understand many systems. The counterparts of one system are found in many others. One major problem at the moment is to recognize these relationships and to capitalize on them.